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PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY

OF GLASGOW.

VOL. XII.

MDCCCLXXIX-MDCCCLXXX.

PUBLISHED FOR THE SOCIETY BY
JOHN SMITH AND SON,
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1881.

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PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

SEVENTY-SEVENTH SESSION.

Opening Address—"On State and Preventive Medicine." By ANDREW FERGUS, M.D., President of the Society.

[Read before the Society, 5th November, 1879.]

ONCE more, gentlemen, you are assembled to listen to an opening address, and I am sure most of you appreciate my difficulty in finding a suitable subject for this Society. At first I felt inclined to give you a sketch of the rise and progress of the Glasgow Philosophical Society, but I have abandoned this for the present, thinking it would be more appropriate as the address at the opening of the new premises. I then resolved to ask you to bear with me while I make a few remarks on a somewhat professional subject, encouraged to take this course by the fact that former Presidents have addressed you on subjects connected with those branches of science on which they were labouring, and with which they were most familiar. As a large majority of our members do not belong to my profession, I hope I shall be able to make my remarks interesting to all by taking up such subjects, and using such language as all can understand. For some time I have been dipping into the subject of Preventive Medicine, both past and present. I shall bring the former subject under your notice to-night, and I hope I shall be able to interest all those who labour for the progress and prosperity of their fellow-men. It was long the prevalent and deep-rooted belief in the public mind, both professional and lay, that the office of mediciners (to use an old Scotch term, which included all the members of the healing art), was merely to *cure* disease, and that their function began and ended with the treatment, and, if possible, the cure of the sick. This led to a twofold evil—1st, It arrested the development of preventive medicine; and, 2nd, it occasioned too great faith in drugs. This evil is more fully developed in the southern part of the island, where the majority of practitioners supply medicines, and have a direct pecuniary interest in the amount their unfortunate patients can be made to swallow. The over-reliance on drugs was illustrated by an old physician, who said that when he began his professional career, he had a hundred remedies for every disease—*now*, he added, I have scarcely one remedy for a hundred diseases. It is gradually dawning on the present age that medical science can possibly do a little more, and that, in addition to the treatment of disease, something may be done towards its prevention. Hence we have what are supposed to be new departments of medical science—namely, Preventive and State Medicine. I use the word *supposed* advisedly, because I hold that State medicine, as a very important branch of the medical profession, is not new, but reaches back into times of the most remote antiquity, and was then probably better understood and more thoroughly carried out than any other branch of the healing art. If you will turn to the 13th chapter of Leviticus you will there find a medical officer of health endowed with absolute authority to separate the sick from the healthy, and also to isolate infected persons so completely as to prevent the disease from spreading further. Due provision is made that the isolated patient be inspected from time to time, so that, in case of recovery, or of the disease assuming a non-infective type, he might be set at liberty. No doubt science has made great progress since the time of the Mosaic dispensation, but if we are ever to get quit of Zymotic diseases it will be by adopting the laws of Moses in regard to them—rigorously separating the sick from the healthy. Let us hope the time is not far distant when every medical officer shall be endowed with the same stringent powers as were possessed in the time of Moses—who, we must not forget, in what he did for Israel, acted directly under the Divine authority and guidance, as well as being learned in all the learning of the Egyptians, at that time the most cultivated race in the world.

No doubt, under the general term leprosy many diseases would be included—possibly all affecting the skin might be so; and hence the humane provision that, after a time of probation and repeated inspection, some were restored to society. It is foreign to my subject to enlarge on this topic, interesting though it is, or to try to trace out the various diseases, such as cancer, leprosy, elephantiasis, &c., which are described in Leviticus. I shall confine myself to the evidence we have in favour of the antiquity of State medicine, and that the most learned body in the community acted as medical officers of health.

It is quite evident that different diseases were dealt with. In verses second and third of the chapter above referred to, leprosy or some other infectious disease is indicated; verse fourth describes a doubtful disease, or at least one without all the symptoms of leprosy, and accordingly the medical officer shuts the patient up for seven days. At the end of that time he is again inspected, and rules are given whereby he may be set free, if it is safe to do so. But if, on the other hand, the disease should be found to have spread, he is pronounced "utterly unclean," and his complete isolation is strictly enjoined in verses 44-45, and succeeding verses—

> "Without the camp shall his habitation be."

We do not hear of leprosy till after the exodus from Egypt, and some have supposed that the prevalence of this disease was the cause of the expulsion.

Everywhere in Jewish history the leper was considered ceremonially unclean—he was isolated from all intercourse with his fellow-men, and he was punished with eighty stripes if he approached the Mountain of the Temple.

The law for the leper was—"His clothes shall be rent, and his head bare, and he shall put a covering upon his upper lip, and shall cry, Unclean, unclean."—Lev. xiii. 45.

Various speculations have been indulged in as to what is meant by the plague of leprosy in garments, and it has been supposed by some to be simply their being saturated by the discharge from the open sores of persons diseased with leprosy. An attentive perusal of the whole passage, however (verses 47 to 59), shows that it must have been something which spread into and destroyed the garment, which could not have been done by any known discharge from a sore.

But, whatever it may have been, the orders in regard to it were equally stringent. After milder means to check its progress have failed, the medical officer uses the most powerful disinfectant we possess—viz., fire. The edict goes forth, "It shall be burnt in the fire:" "Thou shalt burn that wherein the plague is with fire." It is still more difficult to understand what could constitute leprosy in a house. Some have imagined it to have been merely the emanations from the sick, and think the cleansing much of the same nature as the re-papering of a room in modern times after infectious disease; but the passage does not favour such an interpretation, and even the "dry rot" of our own day fails to explain it, as the leprosy was in the plaster and stones of the infected house.

We should rather incline to believe that some sort of fungus growth was indicated; but whatever uncertainty may remain as to the nature of the outbreak, there is none as to the steps to be taken immediately in regard to it. The house was to be emptied and given in charge of the sanitary inspector, and by him shut up for seven days. At the end of that time, if the appearance has spread, he commands that they take away the stones in which the plague is, and cast them into an unclean place without the city. Fresh stones and mortar were then supplied, and the house was again shut up. If the leprosy appeared again, it was to be destroyed utterly, and the materials removed to an unclean place without the city.

It was not among the Jews merely that lepers were thus treated. In the middle ages in other countries they were obliged to live apart from the general community, and if they went abroad they had to intimate their presence in various ways, sometimes by rent clothes, and a cry of "Unclean, unclean;" sometimes by using clappers to signify their approach, or, as in some countries, by wearing two hands of *white* wool (no doubt thus symbolising the nature of their disease), one on the head, and the other on the breast.

So anxious were communities to carry out preventive medicine in the most complete manner, and avoid all possibility of contagion, that the lepers were interred in separate burying-places. Strange to say, sufferers from this disease became dead in the eye of the law, as soon as the disease was fully developed: they could not hold property, nor inherit it, nor dispose of it—in short, they lost all rights of citizenship.

Not content with this, in the middle ages the Church went through the ceremonial of a leper's funeral by a special service, which was retained in the French Ritual till a comparatively recent date. The priest, wearing his stole, and holding up the crucifix, sprinkled the leper with holy water, and conducted him to Church, singing the usual burial verses as they went along. In the Church his clothes were removed, a funeral pall thrown over him, and the mass was celebrated, with the full service for the burial of the dead. He was again sprinkled with holy water, clothed in a leper's dress, and conveyed to a leper hospital, where the priest, to typify his burial, sprinkled him with earth, and warned him never to appear otherwise than barefooted and wearing his black garment—never to enter a church, or any place where corn was ground or bread baked—never even to approach a well or fountain.

It has been supposed that leprosy in Europe was spread by the return of the Crusaders, but there is not sufficient evidence of this, though no doubt it overran Europe about that time, and invaded even the most northern countries; and we can form some idea of its prevalence, when we are told that in the thirteenth century there were upwards of two thousand leper hospitals in France. When the first hospital was founded in Scotland I cannot tell, but at Prestwick there was one, which, if not founded by King Robert the Bruce, was at least amply endowed by him. It is still a matter of dispute whether or not the king himself was a leper. In the year 1350 we learn that the Lady of Lochow built a leper house at the Gorbals of Glasgow; but some hospitals were founded much earlier—even more than two hundred years before the Glasgow institution. Of course these hospitals were not like modern hospitals, numbering their inmates by hundreds; but still, so general was this disease in the kingdom, and so much was the necessity of isolation considered a duty and a safeguard to the community, that there were about one hundred leper hospitals in England and Scotland which were under strict regulations, while the most stringent rules were also enacted to prevent the sick from mixing with the well. In some, under certain precautions, the inmates, on particular days, were allowed to leave to buy provisions, while in others they were punishable by death if they left the hospital, and, to emphasise this regulation, a gallows was erected in front of the leper house. With regard to the Glasgow house, in the Burgh Records for 1573 we find that the then magistrates ordered four persons supposed to be lepers, "to be viseit, and gif they be fund sua, to be secludit of the town to the hospital at the Brigend." In the Parliament held at Perth in 1427, the following is a clause from an Act then passed:—"Item that na lipper folke sit to thig (beg) neither in kirk nor kirkzaird, nor ither places within the burrowes, but at their own hospital, and at the fit of the towne, and other places outwith the Burrowes." The Act afterwards tells us *who* were then the sanitary inspectors. The third clause is as follows:—"That the Bishoppes, offichalles, and deanes inquire diligentlie in their visitation of ilk Paroch Kirk gif one be smitted with lipper, and gif any sic (such) be found in that they be delivered to the King if they be Seculars, and gif they be Clerkes to their Bishoppes, and that the burgesses gur keepe this statute under the paine intimet in the statute of Beggars, ... and quht a leprous that keepis not this statute, that he be banished for ever off that Burgh quhair he disobeyis, and in likewise to landwart." After the Reformation the kirk-sessions took upon themselves the duty of looking after lepers. Of their dealings with them records may be found in their minutes of meetings. Some of the hospitals had ample endowments, but most of them had but scanty permanent support, and derived a precarious income from alms, which were sometimes deposited by passers-by, they being invited to do so by some one or other of the inmates soliciting them by loud cries. Occasionally the lepers were allowed to beg in person, with this protection to the public, that they were obliged to use a clapper to warn people to keep from contact with their person. Another curious source of support was from confiscated food. The Scotch Parliament, in 1366, enacted—"Gif ony man brings to the markit corrupt swine or salmond to be sauld, they sall be taken by the bailies, and incontinent without any question sall be sent to the leper folke, and gif there be no leper folke, they sall be destroyed alluterlie." This shows also that there were inspectors of food in those days. In Dr. Marwick's interesting Extracts from the Burgh Records of Glasgow we meet with frequent notices of leper folk. At page 1, under date January 19th, 1573-4, we find the following entry:—"Marioun Gardiner, dochtir to Steyne Gardiner; Jonet Grhame, Jonet Steward, Robert (blank), fleschour. Quhilkis personnes ar dilatit as lepir, and ordaint to be viseit; and gif thai be fund sua, to be secludit of the toun to the hospital at the Brigend." Next year (January 18th, 1574-5), we find Margaret Gardiner and others banished, or ordered to the hospital. It appears that Margaret Gardiner must soon have returned, as, under date April 19th, we find her and others "all ordanit to be expellit the toun." She must have been rather determined to outwit the authorities, as she is again, with others, in October 11th of same year, "all ordanit to be expellit the toun."

On January 24th, 1578-9, and October 10th, '81, lepers are again dealt with. On May 1st, 1582, we find—"Anent the ordinance to be vptakin anent the lippir folkis quha contempnatlie contrair the auncient statutis of the toun repairis thairin as thai wer haill, and that na infectioun nor euill suld com of thair repair, off the quhilkis lippir sum hes speciall friendis within the toun quha resauis thame and gifis thame intertinement of the auld ordour, and without remeid be prouidit, and the auncient ordour tak effect grit hurt and inconvenient sall cum thairthrow, thairfoir the baillies ordanis the auncient aith to be obseruit and that thay repair bot twa dayis in the oulk, and that in quiet and secreit maner, and gif ony of thair friendis resuis thame in thair houssis thay to (be) puneist at the sicht of the baillies, and ordanis the officiares and watter baillie to cherce this act."

The next notice is more interesting, as showing one of the duties of the then water bailie. I do not know how our present water bailie or his deputy would like to act as sanitary inspector.

"Octr. 22nd, 1588.—Lipper gevin vp be the watter baillie: Andro Lawsoun, merchand (and seven others, two of them being) vnder suspicion."

In the next extract we suppose the same officer is called the water seriand. Oct. 14, 1595.—"The watter seriand is warnit to gif wpe the names of the lipper againe Frydaye nixt, and siclyik is ordanit to warne the contraveneris of the statutes in bying of hering at the watter and topping the same over againe, and thai to ansuer Frydaye nixt."

In October, 1605, the provost, bailies, and council "delt with the whole lippir folk." Their first resolution was, viz.,—"The proveist, baillies, and counsall, has statut and ordainit that give evir Germound Boyle, lipperman, hant or frequent the cumpany of his wiffe within this burgh, and give his spous hant or frequent with him, scho to be bennischit this burgh for ewir." The rest were divided into two classes, one of which was sent to the hospital, the other to remain in their own houses, "vnder sick painis and iniunctiounis as salbe given to thame and thair wyffis."

The regulations for the separation of the plague-stricken were quite as complete and stringent. The sick and their families were obliged to remove out of town. Their friends, under the charge of an officer, could visit them after eleven o'clock, and any one going before that hour was liable to death. The houses were cleaned, and the clothing of the infected was boiled in the open air. The parties who discharged these duties, and those who were employed as bearers of the dead, were obliged to wear a grey gown, with a white St. Andrew's cross before and behind. The bier was covered with a black cloth, with a white St. Andrew's cross. A bell was also attached to it, so that it might ring as it passed along, to warn any person to get out of its way. In September, 1584, the authorities of Aberdeen built ports to prevent the entrance of people who might bring the infection. This does not appear to have been successful, for we find that in May next year the magistrates erected gibbets—"ane at the nearest cross, ane other at the brig of Dee, and the third at the haven mouth, that in case any infectit person arrive or repair by sea or land to this burgh, or in case ony indweller of this burgh receive house, or harbour, or give meat or drink to the infectit person or persons, the man to be hangit, and the woman to be drownit." As recently as 1645, two lads, who had received change at a public house which was shut up on account of the plague, were next day separated from the family, and shut up for a fortnight—their food, &c., being handed in to them. The pocket with the change was cast into the fire.

In Dr. Marwick's work there are several regulations regarding the plague, the first of which we quote somewhat at length.

29th October, 1574.—"The prouest, baillies, and counsale, vnderstandand the contagious seikness callit the pest to be newlie rissen within this realme, and for awaye halding and preseruation of this gud town thairfra, hes witht ane consent diuisit and maid thir statutis and ordinances eftirwrittin.

"In the first, it is statute and expreslie inhibit and forbiddin that na maner of persones, indwellaris or that cumis furtht of Leyth, Kirkcaidy, Dysart, Brwnteland, quhilkis ar ellis infectit and suspect of the said pest, nor yit of ony wther townes or placeis that heireftir sall be suspect or fylit, presume to resort and trawell to this toun, or vse trafficque witht the inhabitantis thairof; and that nane of the inhabitantis of this town trawell towart ony of the saidis placeis or vse ony kynd trafficque with thame, vnder the pain of deid.

"Item, becaus that Edinburght as yit is nocht suspect of the said pest, except Bellis Wynd, thairfor it is statute and ordanit that na persone inhabitant of this town pas to Edinburgt without ane testimonial that thai haue nocht hantit nor trafficque with suspect persones; and that nane be resauit furtht of Edinbrught or vther wspect place but are sufficent testimoniall specifeand quhair fra thai cum, vnder the pane of ten pundis; and gif ony inhabitandis of this town trauellis to ony suspect place and bringis hame ony merchandis or wairis quhairthrow ony infectioun salhappin to cum in this toun, thai nocht reportand ane sufficient testimoniall as said is, the saidis persones bringand the said infectioun to suffer the deid, and thair guddis to fall in eschete alsua."

There are also regulations for strangers, travellers, visitors of brig and water, purchase of herring, pipers, fiddlers, minstrels, and vagabonds.

With regard to the sick it was enacted:—"Item it is statute and ordanit that gif ony persone or persones, induellaris in this towne, happinis fra this tyme furtht to fall seik, that the maister of the house incontinent cum to the visitours and sercharis of the gait or ony of thame and schaw the samyn that thai maye be sichtit; and gif ony persones happinnis to deceis in ony hous within this toun that the maister of the hous sall cum to the visitouris appoyntit for sichting thairof or thai be wyndit, vnder the pane of banisment; and for ferther performyng of this statute, thai haue maid, and depute thir persones vnderwrittin to be sersaris of the toun, ilk ane in the gaittis quhair thai duell, quha sall pas twys on the daye throcht the gait apoyntit to thame, viz., in the mornyng and evinnyng, and visie and inquyre of ilk hous that nane be seik, bot it be schawin to thame be the saidis inhabitandis, and to begyn thairto the (blank) ilk twa thai xv dayis about."

Searchers were appointed for each district of the city, and at night the ports were closed, and the keys left in charge of one of the bailies. The authorities held complete power over property, for the last section is, viz.,—"Item ordanis the Sculehouse Wynd and all the wennellis to be simpliciter condampnit and stekit vp."

On September 28th and 29th, 1584, there are several resolutions regarding the plague, and several individuals are appointed "to attend to the yaird endis, bakyettis, and priwie entressis of this toune."

Again, on October 31st, 1588, the plague being at Paisley, stringent resolutions were again taken with regard to all the ports, some were closed, "Siclyk, it is statut that Lindsayis port, the

Stinking Vennall, and the Gray-freir port to be all closit." All these regulations, "vnder the pane of fyve pundis to be taikin of ilk persone quha contravenis the same."

On June 17th, 1605, the tabuirie was sent through the town "discharging the inhabitandis of Lainrik, Peibilles, or Peddert," from entering Glasgow under the same penalty.

On September 20th, 1606, we find, "Tryell being tane of the seiknes in Archibald Muiris hows and Marionne Walker, his mother, and fund to be the plague, ordanis to be askit of the said Marionne quha last frequentit with hir and quhat scheraris schewr with hir. And quhaevir beis inclosit or commandit in thair howssis be the balleis, quarter maisters, or officeris, in thair names, that dissobeyis, to be haldin as pestiforus personis and transportit to the Muir with thair haill houshaldis and guidis. And ordanis all personis of this towne quha hes doggis or cattis that thai athir keip thame fast or hang thame vnder the paine of ten lib, and thame selfis to be inclosit. And ordanis all strainger begeris to depart of this toune incontinent, vndir the paine of scruging and burneing of them on the cheik and banischement, and quhaevir recaves thame heireftir, or gifis them harbrie within their howssis, to be inclosit with thame and sustenit vpone thair expenssis as thai ar, and quhaevir hes set howssis topwir begeris that may nocht susteine thame selfis that thai find cawtioune for thame to sustein thame selfis and keip thair howssis, and quhat personne findis nocht cawtioune as said is the setteris of the houssis to pay fyve lib, and the begeris, possessouris of the houssis, to be banischit the toune presentlie, and farder ordanis that na bairnis or vthir personis accompany the balleis or quartermaisteris vnder the paine of fyve pund."

On September 30th, 1606, they voted a sum of money for the support of those removed to the Muir.

On 23rd July, 1625, we have the following:—"The prowest, bailleis, and counsell, being certanlie informit of the contageoun of the plage of pestilens within the kingdom of Ingland, at Godis will and pleasour, quhilk daylie incressis, and that ane grait number of mercheantis, burgessis of this burgh, ar daylie passand thairto with mercheant wairis, and cuming bak with wairis to this contrie, and speciallie to this burgh; quhilk is verie dangerus not onlie to this burgh bot to the haill cuntrie about; thairfoir it is statute and ordanet be the saidis proueist, bailleis, and counsell, that na maner of persoun, burges nor inhabitant within the burgh, pas heireftir to the same realme of England without thai first foirsie the prouest and bailleis that thair names may be sett doun in roll, and quhair thai go, that thai may returne testimoniallis with thame, and that James Inglis, customer for the present, gif na custom bill ony sik as passis away vnfoirseing the magistrattis within thair libertie, and that na manner of persoun or persounes presentlie in England be ressauit within the said burghe, and that the customer ressaue not thair enteries before the saids proveist and bailleis be foirsein, that ordour may be tane with thame as accordis for the weill not onlie of this burghe bot for the common weill of the haill contrie about, and eschewing of all danger thairthrow sa far as can be vnder God; to be intimat be oppin proclematioun and sound of drum, certefeing the contravenaris of this present act that thai and ilk ane of thame selbe puneist as accordis."

There are many other curious regulations to be found both in Imperial and Burgh laws. I have merely cited the foregoing to show the antiquity of Preventive Medicine.

Having seen how strict and severe, we might almost say how brutal, were the laws of early times, it becomes an interesting question how all regulations as to preventive measures were allowed to lapse, and not applied to other diseases. It has been imagined that the Reformation might have had some influence on this, but there is no evidence of its being so, and we have already seen that in Scotland the kirk-sessions took charge of the leper hospitals. In the minutes of the kirk-session of Walls, in Shetland, there is a record, under date March 17th, 1742, of a resolution to hold a day of thanksgiving for the extinction of leprosy, and the last mention of leprosy in the same session books is in 1776, where there is an order to separate a leper, and to provide food, which was to be brought daily. It may possibly have been the growth of civil liberty which rendered people impatient at any interference with their domestic concerns, while another reason may be that some zymotics have no outward visible eruption, while in others it is so slight as not to be recognized by the public at large.

It is still difficult to get some people to believe that like produces like, not merely in organic life, but also in the region of epidemic disease. Formerly these diseases were attributed to the direct will of the Almighty, the appearance of comets or other physical phenomena, the conjunction of certain planets, or some other astrologers' nonsense. Possibly, also, as regards some zymotics, they had taken such hold of the community before they were publicly recognized, that it was in vain to attempt to stop their progress. We need not enquire further into the reason why, but simply accept the fact, obvious to all, that till quite recent times no attempt has been made to stay the progress of modern zymotics, or improve the health of the community.

I am tempted to glance at one more effort to mitigate epidemic disease, the terrible effects of which in past times are apt to be lost sight of, and I shall therefore lay before you some of the facts as to the mortality from this disease. By the bills of mortality (London) we find that from 1667 to 1686, out of a total burial of 398,700 persons, no less than 28,459 were fatal cases of small-pox, an average for the whole period of one in fourteen, the maximum being in 1681, when one out of every eight burials was from small-pox, and the minimum in 1684, when only one out of 149 was from this disease. For some years after 1686 measles and small-pox were entered together, but in 1701 they were separated, and for the next 22 years we find that the whole burials were 505,598, of which 36,620 were fatal cases of small-pox—just one in fourteen, as in the former period, the maximum being one in eight in 1710, and the minimum one in sixty-three in 1702.

Small-pox was even more fatal in Glasgow. In 1813 Dr. Robert Watt published tables of the mortality in Glasgow from 1783 to 1812, and gives a summary of the results, from which we find that the average mortality from small-pox in the first period of six years was 19·55 of the whole mortality. In the last six years, 1807 to 1812, when the community had received the benefit of vaccination, the deaths were only 3·90 per cent. of the total mortality. To give you an idea of what this is, I have formed a table of the actual deaths from this disease in Glasgow, and I have added a note of what would have been the mortality, if the fatal cases of small-pox had been as numerous as in Dr. Watt's time, before vaccination was introduced.

MORTALITY IN GLASGOW ARISING FROM SMALL-POX.

Percentage of small-pox deaths to total deaths.

Before vaccination, ...	1783-8	19·55
After vaccination, ...	1807-12	3·90
During last six years, ...	1873-8	·55

If the small-pox mortality in 1873-8 had been at the same rate as it was in 1783-8, the average annual deaths would have been 2,914 instead of 80 only.

If it had been at the London rate—viz., one in fourteen of total deaths—the annual deaths would have been 1,045 instead of 30 only.

So intolerable had small-pox as a scourge become, not merely from the deaths it occasioned, but from the disfigurement and blindness it left behind* that people grasped at any suggestion that proposed to mitigate these evils. The first proposal—viz., inoculation—was introduced into this country by Lady Mary Wortley Montague. It consisted in preparing the party to be operated upon by diet and medicine, and then inoculating him with matter taken from a natural case of small-pox. This is now forbidden by law, but many of you may remember old people who have been inoculated when young. One great objection to this process, however, though the inoculators were slow to allow it, was that every case of inoculation was a new centre of infection, and therefore diffused this deadly poison. Inoculation, like most other suggestions for the public good, met with the most strenuous opposition, and a fierce paper war was the result. I have a number of the pamphlets which were published on both sides of the controversy, some of which are very amusing, while at the same time their perusal conveys a valuable lesson as to patience with, and calm investigation of, the claims of inventors, or self-styled improvements. The best written, and in my opinion by far the cleverest, publication in defence of inoculation, is Mr. Maitland's pamphlet on the subject (London, 1722). This gentleman was well able to speak on the subject, having studied inoculation in the East, and it was he who performed the operation on Lady Mary Wortley Montague's daughter, of which he gives full details. He also, by royal permission, inoculated six condemned criminals in Newgate, and in his second pamphlet he gives the names and ages of these persons, with a full history of the progress of the inoculation in each case. This Newgate experiment settled one or two points on which there had been some doubt. It had not been settled as to whether a person having already suffered from small-pox in the natural way would be susceptible of inoculation. One of these criminals had already had small-pox, and his inoculation did not take, so he purchased his life very cheaply. Another of them afforded an answer to the question whether inoculation was a complete preventative to small-pox. She was employed as a nurse in several cases, and did not take the disease.

Mr. Maitland's genius shines most brightly when answering objections. I regret that I cannot read the whole of his pamphlet on this subject, but must confine myself to a few extracts. He first answers a Dr. Wagstaffe, who had written, condemning the process till further experience. Mr. Maitland says, "Would it not sound somewhat absurd if any one should say to a young physician, 'Pray, sir, don't practice till you have experience!' But it is still more so in this case, because in a practice that is entirely to be laid aside, you can neither have the benefit of your own nor other people's experience." Again, to Dr. Wagstaffe's assertion, "It never came into the heads of the practitioners above mentioned to raise distempers by art in a human body," Mr. Maitland replies: "Then I will be bold to say it never came into their heads to practice physic, which, considered in a true light, is founded upon that single principle of curing natural by raising artificial diseases. What is bleeding, but an artificial hæmorrhagy; purging, but raising an artificial diarrhœa? Does the vomiting produced by a surfeit and that procured by a medicine differ so much as that the one must be called a disease, and the other not? Are not blisters issues, and Setons artificial imposthumations?" Mr. Maitland answers Dr. Wagstaffe page by page: let us quote a little more—"The Doctor's argument from the jarring opinions of the inoculators, if all he says were true, is just as strong against the practice of physic in general, for if nobody was to take any medicine till doctors ceased to differ, I believe the Faculty would starve. May we not with more truth affirm that the anti-inoculators (a word more sonorous and longer by two syllables than that of inoculators), are as inconsistent and changeable in their opinions." He sums up his answers by applying the Doctor's arguments as if they were directed against the Peruvian bark. He says: "A drug that has been only used among slaves, an illiterate, unthinking people, who have the advantage of a warm climate and a spare diet, is not fit to be dispensed to the English, whose blood, speaking of it as national, is the product of the richest diet. Is it not plain, by the diseases that it often leaves behind it, that it spoils the constitution? Witness the jaundice, tumours of the legs, and other cachexies that are often subsequent upon it. Besides, none but empirics can give a medicine of which they are not sure of the dose. Is it not plain that it will not answer the design of preventing the disease for the future? For, notwithstanding the use of this drug, the patient suffers many a relapse. Besides, there are not only one or two, but innumerable instances of people who have died after the use of it, and others who have had a diseased constitution all the rest of their lives. The dispensers of this medicine disagree widely among themselves, both as to the manner of its operation and the dose; some give it in tincture, some in substance, some in greater some in lesser quantities, &c. In fine, there are three letters from a friend in New England, which inform me that many who have taken the bark have suffered very much, and Mrs. D——l, who had taken great quantities of it, actually died. Though I have not myself made use of this medicine, nor seen much of the effects of it, I am well assured that not a fourth part of the diseases it pretends to cure are genuine agues. Before I had seen the practice of this medicine, I affirmed it was impossible it would cure an ague; but I am willing to retract that opinion, being convinced by an experiment that it does so sometimes."

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* De la Condamine estimated that the small-pox destroys, maims, or disfigures one-fourth part of mankind.

Mr. Maitland is even more brilliant when answering a Rev. Dr. Massey, who had preached and published a sermon against inoculation. Mr. Maitland remarks: "But there is still a stronger objection against this practice, for Dr. Massey tells us that it is unlawful, and first introduced by the devil, who ingrafted Job of the confluent sort of small-pox." To this Mr. Maitland replies: "From useful discoveries there can always be drawn important consequences. First, hence learn we, that the small-pox is an ancient disease, for if it was conveyed to Job by some such way as inoculation, the matter must have been taken from somebody infected with the distemper. Secondly, that Sydenham was not the first that began the cool regimen; for Job sat down upon the ashes in the open air; his friends saw him afar off. Thirdly, that his friends were tardy—above three weeks before they came to see him; for in the genuine confluent kind of small-pox it will be that time before they can bear scraping with a potsherd. Fourthly, beloved, this confluent sort of small-pox were more gentle to be sure than the common natural ones, for he seems neither to have had delirium, sore throat, nor shortness of breath; he talked distinctly, and good sense. Now here a question ariseth, whether an honest man can do that which the devil has done? I answer in the affirmative; there are three things mentioned: of the devil's assembling himself (as in this place) with the sons of God, believing, and quoting of Scripture. All these things a good man may not only do, but is bound to do." The whole of his answer to Dr. Massey is well worth reading, but I must content myself with giving you a very few more extracts:—

"But it seems it is a tempting of Providence; and there is no great difference between the devil's proposal to our Saviour to cast himself down headlong and that of inoculation. It is wonderful into what absurdities zeal for an opinion will drive a man, even to assert that there is no difference between a man's running into a danger absolutely unnecessary, and from which nothing but a direct miracle can save him, and a venturing on a small hazard to avoid a much greater. The case, put it as disadvantageously as possible, more resembles that of a person who leaps out of a window for fear of fire, and surely that can never be reckoned a mistrust of Providence, even if he did it before he was much in danger: for nobody can say that God Almighty may not save a man from fire in the ordinary course of His providence. And if a person who, being prompted by his too early fears, had taken this course, and lost his life by the fall, nobody will arraign him of self-murder; he might have done an imprudent, but not a sinful action. The parents who suffer their children to converse with their infected relations, which differs in no moral point from the case of inoculation, would think it very hard to be treated as homicides, or murderers of their children, when the very action proceeds from the contrary principle—extreme tenderness. In the former page it was a presumptuous trust, in this it is an entire mistrust of Providence. He is sure to have the inoculators some way or other—and again they cannot pray for a blessing upon their endeavours, because prayer supposes the use of lawful means."

Further Mr. Maitland remarks: "I am touched with the devout reflections upon Providence that are all along spread through his sermon, to which I subscribe with all my heart, but I cannot so much commend the distorting those great and solemn truths of our holy religion to maintain little party interests and fashionable opinions. The text that is quoted, page 22, that the very hairs of our head are numbered, I take to be a stronger argument against periwigs and shaving, than all that the sermon contains against inoculation. Our hairs of our beards were given us for an ornament by Providence, and it is known that many have catched great colds, with mortal diseases ensuing upon them, by shaving. Is not a man answerable for all the bad effects that follow upon an unwarrantable action that contradicts the very intention of Providence. The peroration is equal to any piece of the whole performance—'let the atheist and the scoffer, the heathen and the unbeliever, disclaim a dependence upon Providence; let them inoculate and be inoculated,' &c. I think this clinches the whole matter, and this reverend gentleman has furnished us with a new sensible and religious test, an atheist or infidel can be found out as a witch by the marks upon his body, and that as it has been intimated already that the devil was the first inoculator, I think it is not impossible that the next zealous preacher upon this subject may prove the cicatrices of inoculation to be the mark of the Beast."

There can be no doubt that, as touching the individual, inoculation was very successful. Fatal cases did occur, but they were a mere fraction as compared with those who died of small-pox taken in the natural way.

As regards the community, however, the results were disastrous, and this can be easily accounted for when we remember that each inoculated person became a fresh centre from which the disease could be spread. The custom was to cause the inoculated person to go as much as possible out into the open air, and at the small-pox hospital parties were inoculated and sent away to mingle with the general community. Instead of being diminished, the deaths from small-pox were actually increased, as will be seen by the following table:—

TABLE OF DEATHS FROM SMALL-POX IN EVERY THOUSAND BURIALS IN LONDON DURING THE 18TH CENTURY.

Periods.	Deaths from Small-pox.
From 1700 till 1711	56·6
1710 — 1721	80·4
1720 — 1731	84·0
1730 — 1741	77·1
1740 — 1751	72·0
1750 — 1761	102·7
1760 — 1771	102·7
1770 — 1781	96·3
1780 — 1791	92·2
1790 — 1801	94·2

During the first twenty years there was no inoculation, and it could not have much effect till many years afterwards. You will observe that the deaths were more numerous in the second half of the century than in the first.

After the severe epidemic of small-pox in Paris in 1763, inoculation was forbidden in that city, and those who wished to undergo it were obliged to retire to the country. Such being the results of inoculation, you can easily understand with what anxiety some other remedy for small-pox must have been sought after, and with what enthusiasm Jenner's great discovery was hailed by some, while by others it was, like everything new, as bitterly assailed. The pamphlets were just as numerous as about inoculation, and not in the least degree more sensible.

I now beg to exhibit two illustrations of the truth of what I have been saying, the first a coloured plate of a "Cow-poxed, ox-faced boy," the other representing a child afflicted with "cow-pox, mange, abscess, and ulcers." Both pictures are from a tract, of which the following is the title-page: "*Cow-pox Inoculation no Security Against Small-pox Infection.* By William Rowley, M.D., Member of the University of Oxford, the Royal College of Physicians in London, Physician to the St. Mary-le-Bone Infirmary author of *Schola Medicinæ Universalis Nova, the Rational and Improved Practice of Physic,* and Public Lecturer on the Theory and Practice of Medicine, excluding false systems, &c., &c., to to which are added the modes of treating the beastly new diseases produced from cow-pox, explained by two coloured copperplate engravings of cow-pox mange, cow-pox ulcers, cow-pox evil or abscess, cow-pox mortification."

Even caricature was enlisted to bring discredit on vaccination. F. Smyth Stewart calls it "A mighty and horrible monster with the horns of a bull, the hind hoofs of a horse, the jaws of the kraken, the teeth and claws of a tiger, the tail of a cow, all the evils of Pandora's box in his belly; plague, pestilence, leprosy, purple blotches, fœtid ulcers, and filthy running sores covering his body, and an atmosphere of accumulated disease, pain and death around him, which had made his appearance in the world, and was devouring mankind—especially poor helpless infants, not by scores only, or hundreds, or thousands, but by hundreds of thousands." The author assists his description by an engraved caricature:—Dr. Jenner and other ministers of vaccination (distinguished from ordinary practitioners of medicine by the addition of cow-tails and horns), are discharging large hampers of children into the mouth of the monster; while another (apparently Dr. Thornton) officiates behind with a spade, and shovels into a nightman's cart the undigested remains of this diet. From the distance are advancing to the rescue, Drs. Moseley, Squirrel, and Rowley, with Messrs. Birch and Lipscombe, "the men the heroes," to whom also an obelisk is erected in the right background. Perhaps it may have been in this unattractive guise that vaccination was first introduced into Philadelphia, where "the leading physician pronounces it too beastly and indelicate for polished society."

The House of Commons asked the College of Physicians to investigate the matter. This learned body took nine months to do so, and after exhausting all sources of information, reported most emphatically in favour of vaccination.

I have not given you this long (and possibly to some of you tedious) retrospect as a mere antiquarian curiosity. My first object was to show the antiquity of the practice of separating those affected with particular diseases from the healthy, which practice must be revived if we wish successfully to combat, and ultimately stamp out, certain zymotics. I had next in view to show the great saving of human life which vaccination has effected, as proved by the tables; and I was also desirous to relate the manner in which inoculation and vaccination were received. Inoculation was denounced by some, but by others most warmly welcomed, without due consideration as to its ultimate effect on the whole mass of the people. Vaccination again was fiercely denounced without due experiment or enquiry. Of course this is no new thing, almost every suggestion for the protection or alleviation of humanity is met in the same kind of way. I have been told of a very eminent medical professor, not yet thirty years dead, who, when the stethoscope was first introduced, tried to bring it into ridicule by speaking of it as a bit of stick, with a fool at one end and a knave at the other. You will recognize his simile as a plagiarism from sturdy Samuel Johnson.

I need not detain you any longer, as instances of the same kind will readily suggest themselves to every one's memory. Let it be our part calmly and dispassionately to consider each new suggestion which may be brought before us by all painstaking, earnest, and trustworthy workers in any department either of science or medicine.

II.—*On the Mechanical Transmission of Sound by Wires, and on Simple Forms of Microphone Receivers.* By W. J. MILLAR, C.E., Secy., Inst. Engineers and Shipbuilders in Scotland.

THE object of the present paper is the description of a series of experiments made by the author upon the transmission of sounds by wires without the aid of electricity, and also the description of some simple forms of microphone receivers, which the author has from time to time arranged when experimenting upon electric transmission of sound.

The author's attention had for some time been drawn to the consideration of mechanical transmission of sound through partition-walls between rooms, and it appeared to him that such transmission might be possible, even although the intermediate connection was much extended.

Some experiments were made with wires, which were at first unsuccessful on account of the proximity of the speaker and hearer, and from not having suitable terminations to the line of wire used.

Further experiments, however, showed that, when the ends of the wire were sufficiently far apart, and by using as terminals simple pasteboard discs, or boxes, no difficulty was experienced in transmitting vocal sounds.

Various experiments were afterwards made from time to time. These experiments were repeated under various conditions as to distance, nature of wire used, and forms and quality of terminal mouth and ear pieces. To enumerate some of the more important experiments:—

1st. About 20 yards of No. 40 copper wire were carried from house to outside, when speaking, singing, breathing, and musical sounds were easily transmitted.

This experiment was arranged in various ways. In the first trial the wire was kept free from touching any intermediate substance, and was kept in a moderate state of tension by the holders of the pasteboard discs used at either end. Afterwards it was found that, with suitable arrangements, the wire could be led from room to room, thus passing round corners, and that several persons could be in communication at the same time by simply joining on other terminals to the main wire.

2nd. Several yards of No. 23 copper wire were carried from one room through an adjoining one and to a room beyond, the *wire* *rested on the carpet*, and was simply tightened a little at each end, and fastened to the floor with a carpet tack. Two attachments were then made of a similar-sized wire, and the doors leading to the rooms in connection were *closed above* the wire.

Conversation, musical, and other sounds were then readily transmitted.

In some after experiments, No. 16 copper wire was found to give better results.

Another, and somewhat similarly-arranged experiment was made, in which the wire was carried from one floor of house to another, and messages transmitted.

3rd. Attachments were made to a line of telegraph wire, and various forms of terminals tried, when it was found that musical and other sounds were readily transmitted. The attachments were made by No. 23 copper wire, and the experiments were tried at distances of 75 and 150 yards. It was found that there was no appreciable loss in the intensity of the sounds at the greater distance, although an intervening post had to be passed. Breathing, whistling, singing, and the sound of a small tuning fork, were readily transmitted. Speaking was indistinct, although the word sounds were discernable.

The author believes that, under more favourable conditions, communications might be made in this manner through considerable distances.

4th. About 50 yards of No. 23 copper wire were laid out on grass, and fastened up at ends to pins; attachments were then made, and vocal and other sounds transmitted.

The terminals used were composed of various materials, and were of various forms—the best results were, however, got when the discs or vibrating parts were of pasteboard. If the discs were set in deep rims, clearness of speech was best got by speaking back a few inches from the mouth-piece. With shallow rims the sounds were sharper, but not of such volume.

The best results were got when the wire was attached to centre of disc. Good results, however, were got, although the attachment was made in various ways.

The wires tried were of copper, steel, and iron; the copper wire, however, gave the most satisfactory results. In the case of the telegraph wire, which would be about ⅛ inch thick, and of iron, the volume of sound was considerable; and, indeed, the volume of sound seemed to be increased with heavy wires.

Some interesting results were got by using a common iron wire fence, and attaching terminals at various points apart in the wires of which it was composed. The fence was made up of six wires of $\frac{3}{16}''$ and $\frac{1}{4}''$ diameter, and had iron supports at every 6 feet of its length.

It was found that speaking, singing, whistling, &c., could be transmitted through distances varying from 20 to 60 yards, and that the sound of the tuning fork passed through 100 yards.

Attachments were made to ordinary bell wires, and speaking, singing, &c., could then be transmitted from one room to another.

In all cases the individual voice could be distinguished, and sounds not immediately addressed to the transmitting disc could be heard. Two persons singing together could be heard very beautifully.

The vibratory movements of the discs were insufficient to cause fine sand strewn upon them to move.

From his experiments, the author believes that a large part of the vibratory movement must take place in the interior of the wire. This at least seems obvious in the case of the wire resting on the carpet, which showed an improvement in clearness of transmission when kept still by resting on the surfaces with which it was in contact.

From the fact that whispering and breathing can be transmitted through considerable distances, it is evident that a very small part of the energy expended at the sending terminal can be lost by inducing permanent strain, or by heating the particles of the wire during the transit, and that, in consequence, with suitable arrangements, messages might be transmitted for considerable distances.

SIMPLE FORMS OF MICROPHONE RECEIVERS.

When carrying out some experiments with the microphone, having a galvanometer in circuit, it occurred to the author that, since the wires during mechanical transmission, as already described, must be in a state of varying strain from the vibratory actions affecting them, then, if the needle of the galvanometer were fixed, a state of strain would be induced on the passage of the current, and that this strain of the particles would elicit sounds. To test this, a few yards of covered copper wire were passed lengthwise along the flat sides of a small bar magnet, and connected with a battery. On placing the magnet to the ear, sounds were at once detected on making and breaking contact. These sounds were intensified by placing the magnet on the lid of a pasteboard box, or, better still, on a piece of tin. With this simple arrangement conversation, singing, and musical sounds were readily transmitted.

Various forms of receiver on this principle have been devised (see Figs. 1, 2, 3, 4, 5), consisting of—

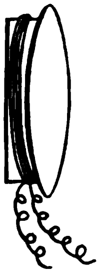

Fig. 1.

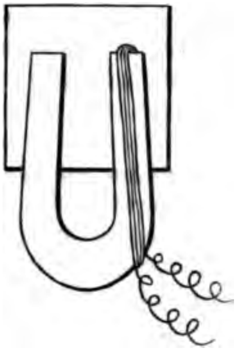

Fig. 2.

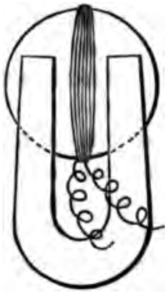

Fig. 3.

(1) Arrangements of bar magnets, as described, having from 6 to 12 yards of covered wire, and placed in wooden and tin boxes.

(2) A horse-shoe magnet, having a few turns of covered wire passed lengthwise along one of its limbs, and a tin plate placed on their flat sides. With these arrangements talking, singing, &c., were readily transmitted.

(3) A few turns of wire passed round a tin plate, the latter being allowed to rest by attraction on the flat sides of the limbs of the horse-shoe magnet, the tin plate and its wire being placed in various positions. It was found that sounds were transmitted by this arrangement, and that the tone varied with the position of the tin plate. It was also found that pieces of wood or cardboard could be used instead of the tin plate in this experiment.

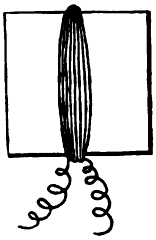

Fig. 4.

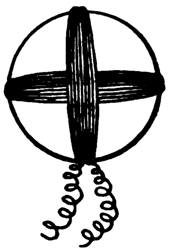

Fig. 5.

(4) Interesting results were got by simply taking a tin plate and wrapping a few yards of wire round it (no magnet being used). Sounds were distinguished on breaking contact, and, when connected with the carbon transmitter, musical and other sounds, such as singing, &c., could be heard; talking could just be detected. The sounds were in this case low, but the effects were quite the same as when the magnet was used.

When using a magnet the strongest sounds were observed near its poles; the tone was deeper near the centre.

Square pieces of tin or ferrotype gave fully stronger sounds than round ones. The plates were allowed to lie as close to the magnet as the magnetic attraction induced them, and in some cases were clamped down.

It was found when the magnetic receivers were placed on the edges of a tin box that the sounds were rendered more generally audible.

A single Leclanché cell was used throughout the experiments enumerated.

From the experiments made the author believes that the sounds originate in the magnet, and that the iron plate, by extending the magnetized surface, reinforces these sounds. Thus, when a large tin plate was placed on the horse-shoe magnet, the vibrations could be detected by hand as a tremor through the metal. Clearness of articulation depended more on the action of the carbon transmitter than upon any nicety of arrangement of the receiver, the latter depending wholly upon the action between the magnetized body and the flow of the current.

The Count du Moncel, in referring to some of the author's experiments in his work on "The Telephone," expresses the opinion that a vibrating diaphragm is not necessary for the reproduction of speech, and that where a diaphragm is used the vibratory movements may arise from the act of magnetization in the centre of the diaphragm.

From various circumstances the author has been unable to extend his experiments, but he believes that the record of the results obtained will be of interest to the members of the Society, who have so courteously offered him the opportunity of placing them at their disposal.

Since reading the paper the author has made some additional experiments upon the mechanical transmission of sound with wires arranged as in some of the recorded experiments, but without any disc or vibrating flat surface at the sounding extremity of the line; and it was found that speaking, singing, and musical sounds could be readily transmitted in this manner. In the case of transmission of speech, the speaker spoke to the wire and close to it; the musical instrument, however, was about 12 feet from the wire. It was also found that the ticking of a watch could be very distinctly heard; the watch simply resting on the wire. From these experiments the author believes that a great part at least of the action of strained wires, as used in buildings for the improvement of the acoustics, is explained by the wires picking up the sounds, and transmitting them to other parts of the building, where their motions either become absorbed, or they cease to have much effect upon the air or parts of the building in their vicinity.

III.—*Disinfection by Acids.* By JOHN DOUGALL, M.D., Fellow of the Faculty of Physicians and Surgeons; Lecturer on Materia Medica, Glasgow Royal Infirmary School of Medicine; and Extra Physician to the Infirmary Dispensary.

[Read before the Philosophical Society of Glasgow, December 3rd, 1879.]

ALTHOUGH disinfection by chemical means has been practised at least since the days of Homer, yet hitherto it has been based on purely empirical grounds. Only within the last few years, sharing in the increased interest taken in sanitary science, has it been made the subject of exact research. Considering the complexity and breadth of the question, the diverse methods by which inquirers have approached and dealt with it, their aggregate results, though as yet small, have the unity and precision of scientific truth. Of late years, perhaps, no material has been so largely used in disinfection as carbolic acid. This may in great part be attributed to the character given it as a surgical application, on the grounds that septic phenomena are caused by bacteria and their allies; that no body is so fatal to these organisms as carbolic acid; and that hence carbolic acid is the most powerful antiseptic. The ardent and painstaking zeal with which these views have been advocated has evoked a spirit of inquiry both into the natural history of bacteria and into the alleged antiseptic and disinfectant powers not only of carbolic acid, but of many other chemical bodies. Of late, also, much has been said and written to show that bacteria form the infecting principle of zymotic poison. If it be argued that the number of zymotic and of infective inflammatory diseases far exceeds the number of known species of bacteria, the reply is, that a single species of these organisms can originate these various distempers, according to the environment. This is tantamont to saying that the environment is rather the cause of the disease, and affects the bacteria, and not the bacteria, as they do not affect the environment; or, in other words, that bacteria are merely passive, harmless, zymotic, and inflammatory products, not active, poisonous, zymotic, and septic causes. However this may be, it is the case that carbolic acid is largely used as a disinfectant in zymotic disease, presumably on the same grounds as it is used as an antiseptic in surgery.

The following remarks being on the destruction of infective matter—on *dis*infection, and not on the preservation of organic matter, or antiseption as practised in surgery—I shall deal chiefly with facts and inferences having a direct bearing on the annihilation of zymotic virus. In an experimental inquiry on this subject, the results of which were published (*Glasgow Medical Journal*, November, 1872, and February, 1873), I found that fresh liquid vaccine lymph, which is true infective matter, contains no bacteria, and ceases to infect when it does contain bacteria, if exposed to the fumes of certain volatile acid bodies *till it had an acid reaction*, permanently lost its infecting power. Moreover, I found that carbolic acid was not one of these bodies—*i.e.*, that lymph exposed for about thirty-six hours to an atmosphere saturated with its vapour did not acquire thereby an acid reaction, and had not lost its infecting power. I further mechanically incorporated about forty parts of carbolic acid with about sixty parts of fluid vaccine, and found that this mixture, after being kept from the air for two days, failed to vaccinate; while a portion of the same preparation, after being freely exposed to the air for twelve days, succeeded in vaccinating. These experiments were repeated with the same results. It was found also that no amount of exposure retrieved the lost infecting power of the lymph, which had been exposed to the other acid fumes until it was acid. These results, I felt, justified me in concluding that carbolic acid was not a disinfectant, not a destroyer of organic matter, but rather an antiseptic, a preserver of organic matter—arresting and preventing putrescent and fermenting change, and suspending zymotic action, for a time proportioned to the quantities of the acid and organic matter mixed, but latterly becoming volatilised, and leaving such matter, whether infective or otherwise, in its original state. From these results I also felt justified in holding that the volatile acid bodies which had permanently annulled the infecting power of the lymph—viz., chlorine; hydrochloric, nitrous, acetic, and sulphurous acids—independent of any antiseptic powers they might have, were at least reliable disinfectants of that substance, and therefore, by inference, of all infective matters.

In Mr. Simon's *Public Health Report*, No. VI., 1875, these views are largely expanded and remarkably confirmed. Here are recorded the details and results of an elaborate and interesting series of experiments to test the disinfecting powers of heat, carbolic acid, permanganate of potash, chlorine, and sulphur-dioxide, on vaccine lymph, liquid and dry, virus of infective inflammation, and virus of glanders. These experiments were planned by Drs. Burdon Sanderson and Baxter, and ostensibly performed by the latter. In eight experiments with a mixture of chlorine and liquid vaccine, it was found that the lymph vaccinated successfully while the mixture was alkaline; but in the ninth, in which the quantity of chlorine incorporated with the lymph had been much increased and the mixture thereby rendered acid, the lymph was deprived of its infective energy. In four experiments in which dry vaccine was exposed to the fumes of sulphurous acid for only ten minutes, its infecting power was destroyed. This acid was also found to be destructive of the virus of infective inflammation, of glander virus, and to be fatal to the growth and multiplication of microzymes—bacteria, and their allies. Mecklenburg (*Berlin. Klin. Wochenschrift*, June 21st, 1869) also found that lymph mixed with an equal volume of acetic acid lost its infecting power; and Davaine (*Comptes Rendus*, Oct. 13th, 1873), that chromic and sulphuric acids were powerful destructives of *charbon* virus. In the course of these experiments, chlorine is also shown to be a good disinfectant, if used in large quantity. Vaccine, as already noticed, is acidized by it, and only then is it rendered inert. Whether the acid formed in the lymph be hypochlorous or hydrochloric, I cannot say; but am inclined to think it the latter. The *rationale* of its action seems explained by saying that the chlorine decomposes the water present, seizing its hydrogen to form hydrochloric acid, while its oxygen is liberated in an uncombined state. Chlorine may thus be said to have a double action: a caustic destructive one, by virtue of the acid it forms; and an oxidizing one, from the oxygen it liberates. The fumes of burning sulphur are, however, far more easily obtained, used, prompt, and effective.

In the report alluded to, carbolic acid is also stated to be a disinfectant, although it further says "that the use of carbolic acid as an aërial disinfectant should be abandoned, owing to the relative feebleness and uncertainty of its action." But the results on which Dr. Baxter ascribed disinfectant powers to carbolic acid are vitiated, especially those with the acid and vaccine, from the fact that the mixture was used in vaccinating *at once or soon* after its preparation, and was kept sealed in capillary tubes till required. As it seemed that two per cent. of the acid added to moist vaccine, and exposure of dry vaccine to the fumes of the acid, prevented it from vaccinating, it was therefore concluded that carbolic acid is a disinfectant. Now, I myself have obtained the same results with moist lymph under similar conditions, and was on the point of forming the same conclusions; but, observing that the carbolized lymph was milky from coagulation when vaccinating, it occurred to me that the reason why it did not vaccinate successfully might be that the infecting particles of the lymph had become covered with the coagulated vaccine fluid in which they are suspended; also that the free acid in the mixture coagulated the contents of the dermal capillaries which are ruptured during vaccination, and so transformed their contents into emboli, while at the same time their walls, being made impervious by the same means, presented an obstacle to endosmotic action. Thus both the vaccine and the nidus of its insertion seemed put in a most unfavourable condition for absorption and absorbing.

To further test this view, I again recently mixed about forty parts of carbolic acid liquefied by a minimum of water with about sixty parts of vaccine. The mixture was then divided in two equal portions on glass slides, and set aside uncovered. In two days afterwards a child was vaccinated with one portion, but without success; this child was successfully vaccinated two weeks subsequently with pure vaccine. The other portion, after it had been intentionally very freely exposed to air and light for fourteen days, vaccinated successfully. This shows that the acid had only temporarily suspended the infecting power of the lymph, and not permanently destroyed it. Dr. Baxter, therefore, in assuming that carbolic acid is a disinfectant at all, has not unnaturally, from the mode of his experiments, mistaken antiseption or preservation for disinfection or destruction. In the able and interesting report by Drs. Braidwood and Vacher on the *Life-History of Contagium*, presented to the Scientific Grants Committee of the British Medical Association, and lately published, are detailed a number of experiments to ascertain the effect of various alleged germicides on vaccine—*i.e.*, as to whether these destroyed its infecting power. Chief among the substances used were carbolic acid, sulphurous acid, permanganate of potash, and chlorine. The reporters say that "Dr. Baxter's conclusions regarding the influence of carbolic acid, sulphur-dioxide, and chlorine (on vaccine), coincide to a great extent with those at which we have arrived." These conclusions are, that "sulphurous acid, chlorine, carbolic acid, and permanganate of potash, destroy the activity of vaccine." With the exception of carbolic acid, I am also of the same opinion, but have the same objections to urge even more strongly against Drs. Braidwood and Vacher's mode of experimenting with vaccine and carbolic acid as already made in regard to Dr. Baxter's. The reporters state, as the results of their experiments, "that the immediate inoculation of a freshly-prepared mixture of vaccine with an equal portion of a one-to-twenty aqueous solution of carbolic acid succeeded (in vaccinating) in some instances" (about 70 per cent. of the inoculations failed). "Such a mixture, preserved for seventeen days to six weeks, failed to produce vesicles." "A mixture of six tubes of vaccine with four drops of one-to-four aqueous solution of carbolic acid failed to produce vesicles." "A mixture of six tubes of vaccine and four drops of carbolate of glycerine containing 20 per cent. of carbolic acid failed to vaccinate."

As regards the first set of these results, it is easy to account for the success which followed inoculation. (The cause of non-success has been already explained.) The mixture of the acid and lymph had simply not been sufficiently long in contact to coagulate the latter, or the two bodies were not thoroughly incorporated previously to inoculation, so that some pure lymph was left in the mixture. It is stated that, in the other experiments with carbolic acid and vaccine, the mixtures were either used at once after their preparation, or kept hermetically sealed in capillary tubes for seventeen days, three weeks, four weeks, and six weeks before being used. It will thus be seen that in every instance the greatest care was taken that the carbolic acid should be kept in close contact with the lymph until the mixture was used for vaccinating. Why all this care? Did the experimenters suspect that, if the mixture were exposed to the atmosphere, the acid would become volatilized and leave the vaccine intact? It will at least be admitted that, although the vaccine had been made permanently inert, the experiments have no practical value in disinfection, in consequence of the relative excessive quantities of the acid used as compared with the amount of vaccine employed; also of the absolute seclusion to which the mixtures were subjected, hermetically sealed in capillary glass tubes; and likewise of the great length of time they were kept in these tubes--seventeen days, three weeks, four weeks, and six weeks. A one-to-twenty aqueous solution of carbolic acid is saturated, and is so strong that few or none acquainted with its properties would think of using it as a disinfectant for sinks or sewers, for which it is only applicable. This solution contains one pound of pure acid to two gallons of water; and if the hand were wet with it for half a minute, it would be numb for a day after. But if this 5 per cent. solution be strong, the other two solutions far surpass it, both containing 20 per cent., being 1 in 5 of the acid, or two pounds of acid to a water. As the acid requires twenty parts of water for gallon of its solution, obviously three-fourths of it must have remained undissolved in these preparations; so that it may almost be said that the lymph was mixed with pure acid. Some of it must have been.

Then, again, in practical aërial disinfection—for example, disinfection of a room in which a patient had died of small-pox —the apartment would require to be, on these data, kept closed for from seventeen days to six weeks; while it would be impracticable to volatilize the quantity of acid in the room required by these experiments, and impossible to confine it as was done in the tubes.

But although I entirely disapprove of the use of carbolic acid as a disinfectant, I believe, nevertheless, that in virtue of its antiseptic powers it may be made to assist in preventing zymotic disease. If it be assumed that decaying organic matter is capable of originating *de novo* infective poison, or of forming a favourable nidus for its multiplication (and that the latter is the case there can be no doubt), then carbolic acid may be added to such matter with benefit, as by its antiseptic properties it will, for a time, prevent decomposition. Should, however, any infective material be present, then the acid, by its antiseptic action, will preserve it, and thus, though it may for a certain period arrest its power of infection, the acid will ultimately, as with the vaccine, become volatilized, leaving the poison free to act.

The experiments of Dr. Baxter generally, but especially those with vaccine, chlorine, and the fumes of sulphur-dioxide, have a much more practical bearing than those of Drs. Braidwood and Vacher. The former exposed one portion of dry vaccine to chlorine gas for thirty minutes, and found its infective power destroyed; and another to the vapour of sulphur-dioxide for ten minutes, with the same result in four different trials. The latter submitted one portion of liquid vaccine to the influence of chlorine gas; and another to the fumes of ignited sulphur *all night* (I presume twelve hours) with the same result. But dried vaccine must obviously be more difficult to disinfect than liquid vaccine; and, as this was done in ten minutes in the one case and thirty minutes in the other, it is manifest that Drs. Braidwood and Vacher exposed their liquid vaccine much too long. If every infected apartment required from twelve hours to six weeks for its disinfection, it is very probable that the process would seldom be done efficiently. Fortunately, however, such is not the case, as it is proved that sulphurous acid and chlorine disinfect with a promptitude easily utilized.

From the general tenour of the preceding, it will be seen that acids are prompt and efficient antizymotics, omitting carbolic acid, of course, which partakes more of the character of an alcohol, andis called an acid because it forms salts with alkalies, while it does not redden blue litmus. It is but natural to think that acids should act thus, from the fact that, so far as known, all infecta have a neutral, but chiefly an alkaline, re action. Such is the case with vaccine, varioline, virus of in fective inflammation, virus of glanders, enteric and choleraic fæcal matter.* Hence acids may act as disinfectants not only by destroying the molecular arrangement of the poisonous substance, but also by changing the nature of its environment.

Disinfection by acids is far from new, sulphurous acid or the fumes of burning sulphur having been used by the Greeks to fumigate their temples after sacrificial rites, and also to destroy the parasites which infested their sheep.

Dr. Lind,† who, considering the state of sanitary science at the time he wrote, must have had very much greater opportunities of seeing the ravages of infectious disease than any of the present generation, says:—"It gives me the highest satisfaction to affirm that I seldom or never knew a proper application of fumes of sulphur to be unsuccessful in effectually purifying all tainted places, materials, and substances. I have known, in several ships where there are the fairest opportunities of trying things of this nature, that the contagion of small-pox has been entirely stopped by means of wood fires sprinkled with brimstone, kept burning and closely confined in the infected place." The following is a crucial experiment. The commission at Moscow, in the year 1770, invented a fumigating odoriferous powder, which, from several lesser experiments, proved efficacious in preventing the infection of the plague. In order more fully to ascertain its virtue in that respect, it was determined towards the end of the year that ten malefactors under sentence of death should, without undergoing any other precautions than the fumigation, be confined three weeks in a lazaretto, be laid upon the beds and dressed in the clothes which had been used by persons sick, dying, and even dead, of the plague in the hospital. The experiment was accordingly tried, and none of the ten malefactors were then infected or afterwards became ill.‡ The chief ingredients in the fumigating powder were nitre and sulphur.

Acetic acid has also long been used as a disinfectant. It is related that Cardinal Wolsey was in the habit of carrying a sponge soaked with this substance and various aromatics, in an orange-skin, when passing through the crowds which his fame attracted, in order to preserve him from infection. The reputation of acetic acid as a disinfectant is said to have arisen from the confession of four thieves, who, during the plague of Marseilles, plundered the dead bodies with perfect security, and, on being arrested, stated, on condition of their lives being spared, that the use of aromatic vinegar had preserved them from the influence of the contagion. It is on this account sometimes called "Le vinaigre des quatre voleurs." Muratori, an Italian physician of the seventeenth century, advocates the use of vinegar as a disinfectant. This substance is also in great favour with the Arabians as such. The late Dr. Mead, who was somewhat sceptical regarding the benefits of fumigation, and advocated the keeping of houses cool and airy, was nevertheless favourable to the use of vinegar and burning sulphur as disinfectants.

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* The urine and fæcal matter of a healthy person are acid when newly voided, but soon after become alkaline. This is an example of nature using acids as anti-putrefactives.

† *Philosophy of Medicine.* London, 1799. Quoted from his *Dissertation on Fevers and Infection,* page 225.

‡ *Philosophy of Medicine.* London, 1799.

In the year 1773, Gayton Morveau brought forward hydrochloric acid as a disinfectant. The gas was to be made by pouring sulphuric acid on common salt, and was recommended as an efficient mode of disinfecting military hospitals, for which it was largely used, and undoubtedly with great success, as the Chancellor of the Legion of Honour in 1805 writes to him as follows, in the name of the Emperor Napoleon:—"Europe and America know that since 1773 you have employed your discovery of the application of muriatic acid fumes to arrest the effects of contagious and direful diseases."* So high was this discovery valued, that for it he was made brevet officer of the Legion of Honour, and a decree was passed by the National Assembly ordering its use in military hospitals where infection prevailed.

In 1780, Dr. Carmichael Smyth began to use nitrous acid fumes as a disinfectant. Fever had broken out among the prisoners in Winchester, which attracted the attention of Parliament. Several eminent London physicians were asked to take charge of the prisoners, but refused. Dr. Smyth latterly agreed to do so. One hundred and eighty of the prisoners, with most of the officers and servants, had already died, and the disease was daily increasing. In Dr. Smyth's own words, "When I arrived at Winchester, I found the hospital in the following state:—

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* *Traité des moyens de désinfecter l'Air, de prévenir la Contagion, et d'en arrêter les Progrès.* 1805.

TABLE OF DEATHS.

Date of Weekly Accounts.	Number of Spanish Prisoners.		
	In Custody.	Sick.	Dead.
March 26, 1780, ...	1247	60	1
April 2, „	1243	106	4
„ 9, „	1475	150	10
„ 16, „	1457	172	18
„ 23, „	1433	142	21
„ 30, „	1412	171	21
May 7, „	1388	191	25
„ 14, „	1351	197	27
„ 21, „	1523	205	30
„ 28, „	1494	226	31
		Total . .	188

Immediately on the admission of the nitrous acid vapour, the deaths fell on June 17th to nine; on the 27th to five; July 1st to five; and July 8th, to one, when the contagion ceased. None after its admission caught it, and the disease immediately showed a milder aspect." A Dr. M'Gregor, of the 88th Regiment, having about this time lost from forty to fifty patients during an outbreak of fever, tried, on a subsequent outbreak of the same disease, nitrous fumigation, and, of sixty-four men seized, did not lose one. The results of Dr. Smyth's application of nitrous acid fumes, not only in Winchester Prison, but in hospitals and ships, produced such an effect on the public mind that Parliament, in 1802, voted him £5,000, and he was appointed physician extraordinary to the King.

There is a substance which demands notice here from its being much used as a disinfectant by German and American sanitarians —viz., ferrous sulphate. If an aqueous solution of this salt be added to healthy fœcal matter, no change ensues in the colour or odour of the mixture; but if it be added to typhoid or choleraic excreta, the whole turns black as ink, while the putrid odour vanishes. Now, I presume it is for such effects that ferrous sulphate is used as a disinfectant. But how does it not blacken and deodorize healthy as well as diseased excreta? It is because the affinity between this salt and the hydrogen sulphide, which is the cause of fœtor, is only exerted in alkaline solutions. Hence, as healthy excreta are acid, this affinity does not come into play, and as typhoid and choleraic excreta are alkaline, it does, blackening the mixture and deodorizing it. But the mere removal of fœtor is not disinfection; and, until those who use this salt as an antizymotic can show that it does more than merely decompose hydrogen sulphide—which, I am sure, will be difficult—I will hold that choleraic and typhoid excreta, however black and inodorous from mixture with ferrous sulphate, are yet infective.

Acids have an action on putrescible fluids which seems to me of much value in a sanitary sense. I have already referred to this in my paper on the Science of Disinfection,* and the numerous experiments by which it was discovered are detailed in my paper on Putrefiers and Antiseptics.† Yet a few remarks on this point may not be out of place. If a clear, fresh, putrescible fluid be set aside for a short time, and then examined by the microscope, it will be found swarming with bacteria and their allies in active motion, fœtid and opaque. Its reaction is neutral; but these changes would ensue though it were made moderately alkaline or *very faintly* acid. If it be now exposed in a cool dark place for from nine to twelve months, and then examined, it will still be found swarming with life, cloudy, fœtid, and containing albumen. In a few months later, putrefactive reduction is completed. The solution may be still cloudy, but is now almost free from fœtor; a bacterium is only seen here and there; a faint trace of albumen may or may not be detected; and its specific gravity, at first perhaps about 1.6, is now probably about 1·1 or 1·2. Such are the chief physical phenomena of putrefaction. As regards its chemical aspects, the chief elements in animal matter are oxygen, hydrogen, carbon, nitrogen, phosphorus, and sulphur. The hydrogen unites with the oxygen to form water; with the nitrogen to form ammonia; with the sulphur, phosphorus, and carbon, to form sulphuretted, phosphoretted, and carburetted hydrogen gases. The oxygen also unites with the carbon to form carbonic anhydride. In course of time the ammonia is oxidized into nitrous and nitric acids and water; the sulphuretted hydrogen into sulphurous and sulphuric acids and water; the phosphoretted hydrogen into phosphoric acid and water. These free acids then at once combine with any bases present to form their respective salts. Putrefaction is thus seen to be a process of reduction; and the greater the number of equivalents of elements forming the atoms of a compound, the more easily does such a compound decompose. This instability is increased in animal substances by their containing nitrogen, which has less tenacity in its affinities than any of the elements. The large quantity of water present also forms a most favourable medium for putrefaction, which only takes place at death, as then the chemical forces by which the living tissues act on vital organic compounds cease, and the elements of the original compounds unite to form bodies less complex, but more stable, as described above.

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* *Transactions of the Social Science Congress.* Glasgow: 1874.

† *Glasgow Medical Journal,* November, 1872, and February, 1873.

If to another portion of the same clear, fresh, putrescible fluid, a quantity of acid, mineral or vegetable, be added, so as to cause marked acidity, and the mixture be then placed under the same conditions as the former, then in a day or two it shows quite a new set of changes. One or more small tufts of mycelia are present, their silky filaments radiating from a tiny nucleus; also numerous free spores and double torulaceous cells. If the proper quantity of acid has been added, no bacteria are present, and the fluid, instead of becoming hazy, becomes clearer and sparkling. Its reaction is of course distinctly acid, its odour somewhat mouldy, but not at all unpleasant; while, in about four months, it ceases to respond to albumen tests, indicating that decomposition is completed. This is fermentation. Again, if to a portion of a putrefying fluid a slight excess of acid be added, putrefaction is soon arrested, and the mixture, instead of being then fetid, has an odour like that of oil of spiræa. And if to separate portions of a fresh and of a fermenting albuminous fluid, a larger quantity of acid be added than is sufficient to cause fermentation alone, then the fresh fluid neither putrefies nor ferments; fermentation is arrested in the fermenting fluid; and both mixtures remain in this antisepted state for an indefinite time, and latterly cease to respond to albumen tests.

Now, these results seem to me strong proofs that putrefaction and fermentation, whatever be the chemical changes they produce on solutions of animal fluids, are distinct processes. There is abundant evidence that putrefying matter is very injurious to health, but there is little or none to show the effects of fermenting matter in this respect. It is obvious, however, that fermentation must be harmless as compared with putrefaction. Putrid matter evolving noxious effluvia for nearly twelve months * must be more

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* I have a bottleful of beef-juice prepared about five years ago, which is still quite putrid: its contents have, however, been kept from air and light. From this can be inferred the time which animal solids may lie festering in a choked or improperly flushed drain.

hurtful than the same matter when fermenting, it being always almost odourless and fully decomposed in about four months. Moreover, as already observed, acids added in excess both prevent and arrest putrefaction and fermentation; and this not by antiseption but by destruction, as is shown by the animal solution ultimately ceasing to respond to the tests for albumen, without the physical signs of either putrefaction or fermentation having been present.

Convinced of the truth of these facts and deductions, I have now for a number of years exclusively practised them in every form of infectious disease, for which there has been ample opportunity both in my capacity as medical officer of health and in private practice. I have watched the effects with scrupulous care and an unprejudiced desire to learn whether, and if so how far, theory and laboratory experiments were confirmed by practice. My experience and observations have further convinced me that disinfection by acids is cheap, quick, easy, and certain: and I have frequently been struck with the summary manner in which an infectious disease has been thus arrested, under circumstances most favourable for its propagation.

About eight months ago I attended a girl, aged six, suffering from scarlatina. The family—besides the father, mother, and a servant girl—consisted of eight children, four older and three younger than my patient, none of whom had had the disease. The house contained four small rooms and kitchen. The girl was kept in a room by herself; none of the family were allowed to see her; but during her illness, which lasted about a month, they remained in the house. The mother nursed the sick girl, at the same time mixing freely with the other children, four of whom had to stay from school, thus greatly increasing their risk of being infected; but as yet none of them have taken the disease.

About five months ago I attended a male, aged about eighteen, son of a sanitary inspector. I found him very prostrate, and covered with a livid scarlatinal rash. Next day he was greatly worse, and the case looked hopeless. The house consisted of two rooms and kitchen, and contained, besides the father and mother, four children, excluding my patient, whose ages ranged from six to sixteen, none of whom had the disease previously. Two days afterwards a brother of the patient turned ill and was fevered. It was assumed that he was sickening with scarlatina, and hence was put in a bed in the same room with the patient; but recovering in a couple of days, he was removed to a friend's house. Briefly, my patient, after a rather protracted illness, with profuse desquamation, quite recovered. The other children lived in the house, and as usual were kept from school. The mother nursed the patient, mixing freely with the rest of the family; and yet, up to the present, none of them have taken the disease.

About two years ago I attended a girl, aged twelve, ill of typhoid. The house consisted of four rooms and kitchen. Besides the father, mother, two servant girls, a sick nurse, and my patient, there were five young children staying in the house. The patient's bowels were very loose for about three weeks. She ultimately recovered; the children were kept at home during her illness; none in the house previously had, nor subsequently took, the disease.

About four years ago I was hurriedly called to see a boy, about six years old. I found him in a state of collapse, and covered with a petechial scarlatinal rash; he died next day. The house consisted of two rooms and kitchen; besides the father, mother, and my patient, other four children stayed in the house, none of whom were sent away, nor had the disease previously, nor were affected soon after. About twelve months subsequently, however, the family still residing in the same house, and the mother having had another child, I was called to see a boy of the same family, aged about five years. He was covered with a bright scarlatinal rash, and ultimately had slight albuminuria during copious desquamation, but made a fair recovery; the domestic arrangements were the same as with the first case. None of the rest of the family were affected.

I could relate a great number of similar cases, but that is unnecessary, as it seems to me obvious, from the highly favourable conditions surrounding those detailed, for the spread of infectious disease, that its arrestment must be greatly, if not solely, attributed to the means of disinfection employed. I do not, however, wish it to be understood that I have been so successful in all my cases of infectious disease, the subtlety, attenuation, and extremely obscure modes of operation of zymotic poisons being such as frequently to baffle most, if not all, attempts to modify or prevent their action. Again, it is next to impossible to get some people to bother themselves in carrying out systematic instructions as to disinfection; they do it either spasmodically or imperfectly. In these latter cases I usually find the results much more unfavourable than where the instructions are faithfully attended to. On the other hand, so far as I can remember, every focus of infection under my care, the spread of which had been so suddenly arrested under conditions most favourable for its transmission as to impress it on the memory, was disinfected entirely to, and sometimes, I thought, beyond, my satisfaction. Moreover, every year of increased experience confirms me in these views.

For disinfecting, I advise the use of three acids—hydrochloric, sulphurous, and aromatic glacial acetic. The hydrochloric consists of one of the strong acid to twenty of water, and is used chiefly to disinfect typhoid excreta, and the bed and body clothes of persons with infectious disease. In typhoid cases, a large cupful of this fluid is put in the vessel before it is used. After being emptied down the water-closet, it is rinsed with another cupful, which is also at once put down the closet, the water running while this is being done. In using this fluid for clothes, these only require to be sprinkled with it, so as to sensibly damp them, allowing them to remain so for about four hours; but of course saturation for about an hour is preferable. With thick woollen clothes, such as blankets, however, an inconveniently large quantity of the acid fluid is needed for saturation. It is worth remembering, in such cases, that wool resists the action of acids far more than cotton or linen, and as this material is more likely, from its porous nature, to retain infection than the latter, it should be subjected longer to the action of the acid. Boiling water is afterwards poured over the acidified clothes, which are allowed to stand for an hour. They are then thoroughly rinsed with warm water till all the acid is got rid of, when soap with soda or potash may be used to wash them. If the acid be not removed, the soap will not form a lather. The solution of this acid may also be used for sprinkling on floors, pouring down sinks, &c.

The sulphurous acid is used exclusively for aërial disinfection, which is done morning and night during the patient's illness, not only in the patient's apartment, but in every room in the house. The process is simple: a piece of live coal is placed on a shovel and powdered sulphur sprinkled on it. The sulphurous fumes thus generated should be made to impregnate the entire atmosphere of the house, until it becomes somewhat irritable. If more fumes have been generated than can be tolerated, the excess is easily got rid of by opening the doors and windows, and by causing what may be still forming to ascend the chimney. Fifteen minutes are sufficient to allow the acid to act each time; but if the apartment be empty, it may be used some hours. Mattresses and carpets can be disinfected by suspending them spread out by the corners with ropes, and allowing the acid to float thickly along the lower surface for ten minutes, then turning them upside down, and repeating the process. Bright metallic surfaces are darkened by sulphurous acid.

The aromatic glacial acetic acid, though more than a hundred times the price of the others, gives great satisfaction in the using, its well-known grateful cooling odour forming a pleasant contrast to the repulsive emanations from the body of an infectious patient. It consists, besides the acid, of the oils of rosemary, neroli, cinnamon, cloves, bergamot, lavender, and rectified spirit. I frequently use this acid as an occasional aërial disinfectant, but never to the exclusion of sulphurous fumes. It is directed to be dropped on a hot shovel and volatilized through the house daily, which is the more effective way; or, where its price is a consideration, a little may be poured occasionally into a small vessel of hot water, placed over the gas in the patient's room, by which means it becomes more gradually dissipated, producing at the same time a constant pleasant odour in the apartment. I have had much satisfaction also in using it dilute—one drachm to one ounce of water—for sponging the body, by which two objects are attained—lowering of the temperature and disinfection of the skin. Almost without exception, patients like this process, and are usually much refreshed by it. In all scarlatinal cases, more especially during desquamation, I invariably direct this to be done twice daily. The practice, so much in vogue, of smearing the skin of a scarlatinal patient during desquamation with lard or warm suet, to prevent the morbific epithelial *débris* from scattering, seems to me highly calculated to injure the sufferer. By this means the mouths of the sebaceous and sudoriparous glands, the very channels through which, in all probability, the poison finds egress from the blood, are plastered up; so that, besides the unpleasantness it causes, it is an effectual way of sealing the infective matter in the body. It looks precisely analogous to hermetically closing every door, window, crack, and crevice in a room where a person is lying soaked with infection. On the other hand, by sponging the skin with the aromatic acid, the infectious scurf is permanently deprived of its dangerous properties, while, at the same time, the numerous orifices of the gland-ducts are cleared of their morbid secretions, thus giving free exit to the poison from the blood. Moreover, it is well known, and has been proved experimentally, that the evaporation and oxidation of most perfume-yielding oils, including those in aromatic acetic acid, generate ozone—a powerful disinfectant. Here, then, is another strong recommendation for sponging the body with the substance in question, as by this means an atmosphere of ozone may actually be made to evolve gradually and constantly from the patient's skin, floating under the bedclothes and enveloping every part of the body.

It has been urged, as a fatal objection to the use of acids in disinfecting enteric excreta, unsupported, however, by any experimental or practical data, that they corrode and destroy the metallic fittings of the water-closet. That this objection, applied to hydrochloric acid, is, for all practical purposes, quite groundless, I have proven hundreds of times; hence it seems to me entirely superfluous to give examples to confute it. One, however, may be cited. A few years since, during an epidemic of typhoid, I attended a young man ill, and who at last died, of the disease. His bowels were very loose, moving more or less about ten times in twenty-four hours for nearly three weeks. During this period about three-quarters of a gallon of strong hydrochloric acid, diluted in the proportion of one of acid to twenty of water, had been used to disinfect his excretions, all of which was put down the water-closet without affecting the fittings in the least perceptible degree.

In order, however, to obtain some exact results on this point, the following experiments were made with the metals used in closet-fittings. Pieces of brass, of copper, of lead, and of cast-iron, each measuring two inches in superficies, were weighed and immersed in two ounces of a liquid consisting of one part of hydrochloric acid in nineteen of water, for twenty-five hours. After this, they were washed in pure water and again weighed, when the weight of the brass, copper, and lead, was found unaltered, while the iron had lost thirteen grains, or 4·33 per cent. of its weight.

I submit that these results are a sufficient answer to those who aver that closet-fittings are injured by at least hydrochloric acid, the substance I prefer, as it is by far the cheapest of the mineral acids. In putting the acid fluid down the closet, the first metal it touches is the copper pan, containing usually several ounces of water, by which it is at once more diluted; then, when the handle is raised, there is a rush of water, causing a further great dilution; and the fluid is next carried into a cast-iron basin, thence through a leaden trap, into an iron or glazed sewer-pipe. The lever and other movable apparatus of the closet are of iron and brass; and they, being situated externally to the pan and basin, the acid fluid does not touch them at all. Now, as iron was the only metal affected of the four used in the experiment, hence it is the only one likely to be affected in the closet; but the iron pan is about a quarter of an inch thick and the soil-pipe about one-eighth, while the acid fluid as it passes over the iron basin is diluted to at least 1 in 100, and when it goes down the iron soil-pipe to at least 1 in 500; moreover, the time of contact is but a few seconds. Hence it is obvious, considering that the iron in the experiment was in contact with the strong acid fluid for twenty-five hours, that the action of this fluid on the iron of a water-closet must be extremely little. Even supposing the strong acid fluid were to act *per se* on the iron of a closet, say for ten seconds ten times daily during three weeks, as might be required in a bad case of typhoid, and as was in the case mentioned; yet, on the data of the experiment with the iron, it would take nine hundred days, or about two years and a half, at this rate to dissolve six-and-a-half grains off each square inch of surface of the iron.

In conclusion, it may be stated, as a summary of the foregoing, that putrefaction may be prevented, neutralized, or arrested, or its odour masked or neutralized, and yet any infective matter present be, in all probability, unaffected, preserved, or only made dormant for a brief period, as exhaustive experiments with carbolic acid and infective fluids, more especially with vaccine, show; that to use purely antiseptic substances as antizymotics is highly paradoxical, preservation being practised and destruction anticipated; further, that the mineral acids are true disinfectants, operating by both physical and chemical destruction, and also by transformation, of organic molecules, as in fermentation; hence they prevent and arrest putrefaction, they transform putrefaction into fermentation; they deodorize; and, moreover, they are highly antizymotic as regards vaccine, virus of glanders, virus of infective inflammation, and therefore, by inference, as regards all other infections.

THE PRESIDENT'S OPENING ADDRESS TO THE CHEMICAL SECTION.

IV.—*On the Antiquity of the Chemical Art.* By James Mactear, F.C.S., F.C.I., Member of the International Jury, Paris, 1878, and Medalist of the Society of Arts.

[Read before the Section, December 8th, 1879.]

The study of the History of Chemistry as an art, or as a science, is one which possesses peculiar fascination for its votaries. It has been the subject of deep research and much discussion, much has been written upon the subject, and many theories have been broached to account for its origin. We have had laid before us by Professor Ferguson, in his papers on this subject of Chemical History, very clearly and fully the generally-accepted position as regards the origin of the science, and in the last of these papers, entitled "Eleven Centuries of Chemistry," he deals with the subject in a most complete manner, tracing back through its various mutations the development of the science to the time of Geber, in or about the year A.D. 778.

Of Geber, as a chemist, Professor Ferguson writes, "He was the first—because, although he himself speaks of the ancients, meaning thereby his forerunners, nothing is known of these older chemists."

Rodwell, in his "Birth of Chemistry," after a careful examination of the question, comes to the conclusion that, "in spite of all that has been written on the subject, there is no good evidence to prove that alchemy and chemistry did not originate in Arabia not long prior to the eighth century, A.D.," bringing us again to the times of Geber.

He is not alone in this opinion, and it seems to be generally accepted that chemistry originated in the Arabian schools about this period.

In dealing with the question of the antiquity of chemical art, it has been too much the habit to look at the question with a view of discovering when and who it was that first brought forth, fully clothed as a science, the art of chemistry.

Let us look at the definition of the science given by Boerhæve, about 1732. He describes chemistry as "an art which teaches the manner of performing certain physical operations, whereby bodies cognizable to the senses, or capable of being rendered cognizable, and of being contained in vessels, are so changed by means of proper instruments as to produce certain determinate effects, and at the same time discover the causes thereof, for the service of the various arts."

Now, it is amply evident that, long before the various known facts could be collected and welded into one compact whole as a science, there must have existed great store of intellectual wealth, as well as mere hereditary practical knowledge of the various chemical facts.

I do not think it will be disputed that, until comparatively recent times, technical knowledge has constantly been in advance of theory, and that it is not too much to conclude that, no matter where we first find actual records of our science, its natal day must have long before dawned. Even in our day, when theoretical science, as applied to chemistry, has made such immense strides, how often do we find that it is only now that theory comes in to explain facts, known as such long previous, and those engaged in practical chemical work know how much technical knowledge is still unwritten, and what may even be called traditionary.

I purpose taking up the subject from this point of view, and attempting, with what little ability I can, to follow back to a still more remote period than that of Geber and the Arabian school of philosophers the traces of what has often been called the divine art.

An aspect of the question that has often presented itself to me is this, that the history of what we call our world extends over some 4000 years before Christ and 1878 years since, so that, according to the usually accepted idea, if chemistry originated in Arabia in the eighth century, it was not known during say the first 5000 years of the world's history, but has advanced to its present high position amongst the sciences in the last 1000 years.

I hope to be able to show that, while the Arabian school of philosophy get the credit of originating most of the sciences, that it is as undeserved in the case of chemical science as in that of astronomy or mathematics. At the same time let us not undervalue the services rendered to science by this school: it is to them we owe the distribution of the knowledge of most of our sciences, and the Arabic literature of most of these was widely spread abroad over all the known world of their time.

The central position of Baghdad between the eastern and western portions of the Old World, and the wise and enlightened policy of its rulers, which welcomed to its schools, without reference to country or creed, the wise and learned men of every nation, drew to it as to a centre the accumulated wisdom and knowledge of both the rising and the setting sun. Long ere this time, however, we find, as regards the Greeks, that they constantly travelled eastward in search of learning, while we know that the expedition of Alexander the Great, about B.C. 327, in which he traversed a considerable portion of India, had already opened up the storehouses of Indian lore to the minds of the West.

In connection with this, the following extract from an old book called *The Gunner*, dated 1664, is interesting:—

"In the life of Appolonius Tyanæus, written by Philostratus "1500 years ago, we find, in reference to the Indians called Oxydra: "These truly wise men dwelled between the rivers Hyphasis and "Ganges; their country Alexander the Great never entered, being "deterred, not by fear of the inhabitants, but, as I suppose, by "religious considerations, for had he passed the Hyphasis, he might "doubtless have made himself master of the country all round him; "but their cities he could never have taken, though he had led a "thousand as brave as Achilles or ten thousand such as Ajax to "the assault. For they come not out into the field to fight those "who attack them; but these holy men, beloved of the gods, over-"throw their enemies with tempests and thunder-bolts shot from "their walls.

"It is said that Egyptian Hercules and Bacchus (Dionsyius), "when they overran India, invaded this people also, and having "prepared warlike engines, attempted to conquer them. They "made no show of resistance, but upon the enemy's near approach "to their cities they were repulsed with storms of lightning and "thunder hurled upon them from above."

May we not here have the original of the Greek fire, that was in its day so celebrated and so destructive?

Beginning then at the period of Geber, about 776 A.D., let us try to work backwards and trace, if we can, the progress of chemical knowledge down the stream of time.

While the Western Roman Empire had fallen, the Eastern still held its sway as far as the rivers Tigris and Euphrates, and continued the contest with the Persian power for the supremacy in Asia. At this time the various creeds and beliefs of the Arabian tribes—which had been much influenced by the settlement amongst them of Jews who had been dispersed at the time of the destruction of Jerusalem, and many of the sects of Christians who had been driven from the Roman empire by the more orthodox—were deeply stirred by the new doctrine of Islam, preached by Mahomet, A.D. 622, proclaiming the Koran as the rule of life, and the destruction of the ancient Arabian worship of the stars and sun and moon.

The religion of "the one God and Mahomet his prophet" took deep root, and the injunction to pursue the unbelieving with fire and sword was followed out with such unrelenting vigour that, within less than a century from the death of Mahomet, the Arabian power had extended its sway amongst nearly every tribe and nation that had owned the rule of the Roman or Persian empires, and had reached from Spain to India, from Samarcand to the Indian Ocean.

Egypt and Syria were conquered between A.D. 632-39, and Persia about A.D. 632-51. Their attempts to take Constantinople by siege failed both in A.D. 673 and 716. But they were more successful on the African shores of the Mediterranean, which they swept along till they crossed the Straits of Gibraltar and entered Spain in A.D. 709. Their further progress—through France—was stayed by their defeat in a great battle fought at Tours, when the Gauls, under Charles Martel, forced them to retire ultimately across the Pyrenees.

Internal dissension had, however, arisen amongst them, and the ruling dynasty of the Ommiades was overthrown in A.D. 750 by the Abassides, who established themselves at Damascus; and with them began that cultivation of the arts and sciences which has thrown such lustre on the Arabian school.

One of the princes of the Ommiades who had escaped made his way to Spain and there re-established the power of his family, with Cordova as a centre, about A.D. 755. Thus it was that the Saracenic power was divided into an Eastern and a Western Caliphate.

It was under the prosperous rule of the Abassides that such an impulse was given to learning of every kind, and that the Arabian school of philosophy, which has left behind it such glorious records of its greatness, was founded. The Caliph Al-Mansour was the first, so far as we know, who earnestly encouraged the cultivation of learning; but it was to Haroun Al-Raschid, A.D. 786-808 (?), that the Arabians owed the establishment of a college of philosophy.

He invited learned men to his kingdom from all nations, and paid them munificently; he employed them in translating the most famous books of the Greeks and others, and spread abroad throughout his dominions numerous copies of these works.

His second son, Al-Mamoon, while governor of the province of Kohrassan, we are told, formed a college of learned men from every country, and appointed as the president John Mesue, of Damascus. It is said that his father, complaining that so great an honour had been conferred on a Christian, received the reply—"That Mesue had been chosen, not as a teacher of religion, but as an able preceptor in useful arts and sciences; and my father well knows that the most learned men and the most skilful artists in his dominions are Jews and Christians."

That this was the case can scarcely be doubted when we consider that the Jews had always been familiar with many arts and sciences, and that, as is well known, at the destruction of Jerusalem in A.D. 70, when the Jews were dispersed in every direction, they spread over, not alone the countries under the Roman rule, but to Greece, Egypt, and the Mediterranean coast, as well as great part of Asia Minor, carrying with them, not only their peculiar religious traditions, but also their arts, which, we know, especially as regards the working of metals, were of no mean order, and their sciences, of which the so-called magic and astrology had been assiduously cultivated.

In Asia the dispersed Jews established patriarchates at Tiberias in the west, and at Mahalia, and afterwards at Baghdad, for the Jews who were beyond the Euphrates.

Seminaries were founded at these centres for the rabbis, and constant intercourse was kept up between them. It was in these schools that the Talmud was compiled from the traditionary exposition of the Old Testament, between A.D. 200 and A.D. 500, when it was completed, and received as a rule of faith by most of the scattered Jews.

That the cultivation of science was not neglected we may be sure from the keen interest taken in all ages by the Jews in magical and astrological inquiries. We read in Apuleius, in his defence on the accusation of magic brought against him, that of the "four tutors appointed to educate the princes of Persia, one had to instruct him specially in the magic of Zoroaster and Oromazes, which is the worship of the gods." Apuleius wrote about 200 A.D., and his works teem with references to magic and astrology.

The fact that Jews and Christians were looked on as learned men will not surprise us, when we find that the Jews had established schools so long anterior to the foundation of the college of Baghdad. The rapid progress made by the Arabians, and the wise policy of the Abasside Caliphs, under whose judicious rule learning was so liberally encouraged, aided by the position of Baghdad, which formed, as it were, a centre to which the wisdom of both eastern and western minds gravitated, attracted to their schools all those of every nation who boasted themselves philosophers.

The first translations from the Greek authors are supposed to have been made about A.D. 745, and are known to have been on the subjects of philosophy, mathematics, astronomy, and medicine. These translations are understood to have been made by Christian or Jewish physicians.

As we have seen, the Jews had already established themselves at Baghdad, and had founded schools of their own previous to the formation of the college under Caliph Al-Mansour; but further than this we find the Christians spread widely over the countries of Asia Minor, and we are told, on the authority of Cosmo-Indicopleustes, that so early as A.D. 535 there was in almost every large town *in India* a Christian Church under the Bishop of Seleucia.

With these facts before us—1st, that Christian physicians were the leaders of the Arabian school in the eighth century; 2nd, that large numbers of Christian churches were actually in existence in India at least two hundred years previously to the establishment of the college at Baghdad; and 3rd, that Baghdad was almost, as it were, the central point of the great caravan route which from time immemorial had been the course of communication between the East and West, can we doubt that an extensive intercourse must have taken place, and should we not expect to find some traces, if not the effects, of Indian science on the teaching of the Arabian school.*

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* As to communication, the case of Saggid Mahmud (given in Bellew's *Indus to the Tigris)*, who, merely to pray for the recovery of his sick son, travelled with him from Ghazni by way of Kandahur and Shikarpúr to Bombay, thence by way of sea to Baghdad, from there to Karbola, and back to Baghdad; and then by Kirmanshah and Kúm to Teheran, on his way home to Ghazni, gives an indication of the long journeys taken under the most frightful difficulties. This long journey had occupied six months only, and we read that in former times twelve years were sometimes taken in trading journeys.

In Vol. VIII. of the Journal of Education we find a notice that "Professor Dietz, of the University of Königsberg, who had spent "five years of his life in visiting the principal libraries of Germany, "Italy, Switzerland, Spain, France, and England, in search of manu- "scripts of Greek, Roman, and Oriental writers on medicine, is now "engaged in publishing his 'Analecta Medica.'

"The work contains several interesting papers on the subject of "physical science among the Indians and Arabians, and communi- "cates several introductory notices and illustrations from native "Eastern writers. Dietz proves that the late Greek physicians "were acquainted with the medical works of the Hindus, and "availed themselves of their medicaments; but he more particularly "shows that the Arabians were familiar with them, and extolled "the healing art, as practised by the Indians, quite as much as that "in use among the Greeks.

"It appears from Ibu Osaibe's testimony (from whose biogra- "phical work Dietz has given a long abstract on the lives of Indian "physicians), that a variety of treatises on medical science were "translated from the Sanscrit into Persian and Arabic, particularly "the more important compilations of Charaka and Susruta, which "are still held in estimation in India; and that Manka and Saleh— "the former of whom translated a special treatise on poisons into "Persian—even held appointments as body-physicians at the Court "of Harun-al-Raschid."

As the age of the medical works of Charaka and Susruta is incontestably much more ancient than that of any other work on the subject (except the Ayur Veda)—as we shall see when we come to consider the science of the Hindoos—this in itself would be sufficient to show that the Arabians were certainly not the originators of either medical or chemical science.

We should not forget that it is only to their own works and their translations, chiefly by the Greeks, we owe our knowledge of the state of Arabian science, and that it is only in rare cases that we have given a list of works consulted, so that we can gather the sources from which their knowledge was derived. It would scarcely be imagined, from reading the works of Roger Bacon, or of Newton, that they had derived some, at least, of their knowledge from Arabian sources; and yet such is known to have been the case with them both.

Let us now glance backwards from the Arabians to the Greeks.

It is supposed that the first translations from the Greek authors were made for the Caliphs about 745 A.D., and were first translated into Syriac, and then into Arabic. The works of Aristotle, Euclid, Ptolemy, Hippocrates, Galen, and Dioscorides are known to have been translated under the reign of Al-Mansour.

Granting for the moment that the first knowledge of the sciences was obtained by the Arabians from the Greeks, we are at once face to face with the question, From whence did the Greeks obtain their knowledge? To any careful reader it will be clear that Grecian science and philosophy, like Grecian theology, was not of native birth. It is comparatively well known that the Greeks were indebted to the Egyptians for much of their theology as well as science. The great truths which really underlay the mysterious religious rites of Egypt seem to have been altogether lost when the Greeks wove their complicated system of theology; and we read that the Egyptian priests looked on the Greeks as children who failed to understand the great mysteries involved in their religious rites, disguised as they were in symbolic form. But, besides their indebtedness to Egypt, we will find that they also owed much to Persia, and through it again to Indian sources of knowledge.

There was constant communication between the Grecian and Persian nations. We learn that it was not uncommon for Grecian generals to take service under the Persian Satraps, tempted by the liberal recompence with which their services were rewarded. About the year 356 B.C. this system of Greeks accepting service under Persian Satraps nearly caused the outbreak of war between Greece and Persia—Chares, a Grecian commander, having assisted with his fleet and men, Artabanus, the Satrap of Propontis, who was then in revolt against the Persian king. But before this, during the great plague which desolated Athens in 430 B.C., and which also extended to Persia, Hippocrates was invited to go to the Persian Court; and it is on record that Ctesias was for seventeen years physician at the Persian Court about 400 B.C., during which period he wrote his history of Persia, and an account of India, which Professor Wilson, in a paper read to the Ashmolean Society of Oxford, has shown to contain notices of the natural productions of the country, "which, although often extravagant and absurd, are, nevertheless, founded on truth."

There were, too, Grecian soldiers employed as paid auxiliaries, and a colony of Greeks who had been taken prisoners of war was founded within a day's journey of Susa.

The great expedition to Persia, and the graphic description of the retreat of the "ten thousand" Greeks, given by Zenophon in his Anabasis, must have been well known to Alexander the Great when he set out on his career of conquest. He overthrew the Persian empire in 331 B.C., having destroyed Tyre and subdued Egypt in the previous year and carried his triumphant progress to the banks of the Indus, and there he "held intercourse with the learned sages of India." On Alexander's death Seleucus succeeded to the throne of Persia in 307 B.C., and not long after he forced his way beyond the Indus, and ultimately as far as the sacred river Ganges. He formed an alliance with the Indian king Sandrocottus (otherwise known as Chandra-gupta), which was maintained for many years, and it is said, also, that he gave his daughter in marriage to the Indian king, and aided him with Grecian auxiliaries in his wars.

He sent an expedition by sea, under the command of Patrocles his admiral, who visited the western shores of India, and a little later he despatched an embassy under Megasthenes and Onesicrates, the former of whom resided for some years at the "great city" of Palibothra (supposed to be Patna).

Not long after Megesthenes was at Palibothra, Ptolemy Philadelphus sent an expedition overland through Persia to India, and later Ptolemy Euergetes, who lived between 145-116 B.C., sent a fleet under Eudoxius on a voyage of discovery to the western shores of India, piloted, as is said, by an Indian sailor who had been shipwrecked, and who had been found in a boat on the Red Sea. Eudoxius reached India safely, and returned to Egypt with a cargo of spices and precious stones.

The proof of very ancient communication between Greece and India is quite clear, both by way of Persia and Egypt, and we find that the Greeks, who were in the habit of calling all other nations barbarians, speak constantly with respect of the gymnosophists—called "Sapientes Indi" by Pliny. We read also of the Greek philosophers constantly travelling eastward in search of knowledge, and on their return setting up new schools of thought. Thales, it is affirmed, travelled in Egypt and Asia during the sixth century B.C., and it is said of him that he returned to Miletus, and transported that vast stock of learning which he had acquired into his own country.

He is generally considered as the first of the Greek philosophers. Strabo says of him that he was the first of the Grecian philosphers who made inquiry into natural causes and the mathematics.

The doctrine of Thales, that water was the first elementary principle, is exactly that of the ancient Hindoos, who held that water was the first element, and the first work of the creative power. This idea was not completely exploded even up till the 18th century. We find Van Helmont affirming that all metals, and even rocks, may be resolved into water; and Lavoisier, so lately as 1770, thought it worth while to communicate an elaborate paper "On the nature of water and the experiments by which it has been attempted to prove the possibility of converting it into earth."

Pythagoras, perhaps the greatest of all Greek philosophers, it is known, travelled very widely, spending no less than twenty-two years in Egypt. He also spent some considerable time at Babylon, and was taught the lore of the Magi.

In the famous satire of Lucian on the philosophic quackery of his day (about 120 A.D.), "The Sale of the Philosophers," we have a most interesting account of the system of Pythagoras.

Scene—A Slave Mart. Jupiter, Mercury, philosophers, *in the garb of slaves, for sale. Audience of buyers.*

Jupiter.—Now, you arrange the benches, and get the place ready for the company. You bring out the goods and set them in a row; but trim them up a little first, and make them look their best, to attract as many customers as possible. You, Mercury, must put up the lots, and bid all comers welcome to the sale. Gentlemen,—We are here going to offer you philosophical systems of all kinds, and of the most varied and ingenious description. If any gentleman happens to be short of ready money he can give his security for the amount, and pay next year.

Mercury (*to Jupiter*).—There are a great many come; so we had best begin at once, and not keep them waiting.

Jupiter.—Begin the sale, then.

Mercury.—Whom shall we put up first?

Jupiter.—This fellow with the long hair—the Ionian. He's rather an imposing personage.

Mercury.—You, Pythagoras, step out, and show yourself to the company.

Jupiter.—Put him up.

Mercury.—Gentlemen, we here offer you a professor of the very best and most select description. Who buys? Who wants to be a cut above the rest of the world? Who wants to understand the harmonies of the universe, and to live two lives?

Customer (*turning the philosopher round and examining him*).—He's not bad to look at. What does he know best?

Mercury.—Arithmetic, astronomy, prognostics, geometry, music, and conjuring. You've a first-rate soothsayer before you.

Customer.—May one ask him a few questions?

Mercury.—Certainly—(*aside*), and much good may the answers do you.

Customer.—What country do you come from?

Pythagoras.—Samos.

Customer.—Where were you educated?

Pythagoras.—In Egypt, among the wise men there.

Customer.—Suppose I buy you, now, what will you teach me?

Pythagoras.—I will teach you nothing—only recall things to your memory.

Customer.—How will you do that?

Pythagoras.—First, I will clean out your mind, and wash out all the rubbish.

Customer.—Well, suppose that done, how do you proceed to refresh the memory?

Pythagoras.—First, by long repose and silence, speaking no word for five whole years.

Customer.—Why, look ye, my good fellow, you'd best go teach the dumb son of Crœsus! I want to talk and not be a dummy. Well—but after this silence, and these five years?

Pythagoras.—You shall learn music and geometry.

Customer.—A queer idea, that one must be a fiddler before one can be a wise man!

Pythagoras.—Then you shall learn the science of numbers.

Customer.—Thank you, but I know how to count already.

Pythagoras.—How do you count?

Customer.—One, two, three, four——

Pythagoras.—Ha! what you call four is ten, and the perfect triangle, and the great oath by which we swear.

Customer.—Now, so help me, the great ten and four, I never heard more divine or more wonderful words!

Pythagoras.—And afterwards, stranger, you shall learn about Earth, and Air, and Water, and Fire—what is their action, and what their form, and what their motion.

Customer.—What! have Fire, Air, or Water bodily shape?

Pythagoras.—Surely they have; else, without form and shape, how could they move! Besides, you shall learn that the Deity consists in Number, Mind, and Harmony.

Customer.—What you say is really wonderful.

Pythagoras.—Besides what I have just told you, you shall understand that you yourself, who seem to be one individual, are really somebody else.

Customer.—What! do you mean to say I'm somebody else, and not myself, now talking to you?

Pythagoras.—Just at this moment you are; but once upon a time you appeared in another body, and under another name; and hereafter you will pass again into another shape still.

(After a little more discussion of this philosopher's tenets, he is purchased on behalf of a company of professors from Magna Græca for ten minæ. The next lot is Diogenes, the Cynic.)

Apuleius says in the Florida, Section xv., in reference to Pythagoras, that he went to Egypt to acquire learning, "that he "was there taught by the priests the incredible power of ceremonies, "the wonderful commutations of numbers, and the most ingenious "figures of geometry; but that, not satisfied with these mental "accomplishments, he afterwards visited the Chaldæans and the "Brahmins, and amongst the latter the Gymnosophists. The Chal-"dæans taught him the stars, the definite orbits of the planets, and "the various effects of both kinds of stars upon the nativity of men, "as also, for much money, *the remedies for human use derived from* "*the earth, the air, and the sea* (the elements earth, air, and water, "or all nature).

"But the Brahmins taught him the greater part of his philosophy "—what are the rules and principles of the understanding; what "the functions of the body; how many the faculties of the soul; "how many the mutations of life; what torments or rewards "devolve upon the souls of the dead, according to their respective "deserts."

There is ample evidence, therefore, that the Greeks had communication with, and borrowed the philosophy of, both Persia and India at a very early date.

That there was intimate intercourse with India in very ancient times there can be no doubt. In addition to the classical sources of information collected chiefly by the officers of Alexander the Great, Seleucus and the Ptolemies, and which was condensed and reduced to consistent shape by Diodorus, Strabo, Pliny, and Arrian, within the first century before and the first century after Christ, we have the further proof of the fact by the constant finds of innumerable Greek coins over a large portion of north-western India, and even at Cabul. These, so far as yet known, commence with the third of the Seleucidæ, and run on for many centuries, the inscriptions showing that the Greek characters were used in the provinces of Cabul and the Punjab even so late as the fourth century A.D. The consideration of these coins of the Græco-Persian empire of the Seleucidæ naturally leads us to the consideration of the Persians.

I have already shown that the Greeks and Persians held intimate relations with each other as early as the fourth century B.C., and from the speech of Demosthenes against a proposed war with Persia, delivered in 354 B.C., we may well believe that they had already had a long and intimate connection with each other. The passage reads thus:—

"All Greeks know that, so long as they regarded Persia as their "common enemy, they were at peace with each other, and enjoyed "much prosperity, but since they have looked upon the King (of "Persia) as a friend, and quarrelled about disputes with each other, "they have suffered worse calamities than any one could possibly "imprecate upon them."

The Persian empire was founded by Cyrus, about B.C. 560, and rapidly rose to be perhaps the greatest power of the world of that age. The rise of the Persian empire is not unlike that of the Arabian power in regard to the wide range of conquest achieved in a very limited period. Its actual existence, from the foundation of the empire by Cyrus in B.C. 560 to the death of Darius III., was barely two centuries and a half.

Previous to the Persian empire there existed three principal powers in Asia—the Medes, the Chaldæans or Babylonish, and the Lydian. Of these the Medes and Chaldæans were the most ancient, and their joint power would seem to have extended eastward as far as the Oxus and Indus.

Of these nations the Babylonians were the most highly civilized, and, did time permit, we might find much that would interest and instruct in examining the various facts relating to the arts and sciences amongst these nations. We know that arts and sciences must have been diligently cultivated amongst them, and that magic and astrology were held in high repute.

That the Persians were well acquainted with other nations is shown clearly from the remains of their great city of Persepolis, where the sculptured figures represent many types of mankind—the negro, with thick lips and flat nose, and with his crisp, wooly hair, clearly cut; and the half-naked Indian, with his distinguishing features, being easily singled out from many others.

Persia held sway over a large district of India—the limits of this are not known; but, in addition, they were well acquainted with a large portion of the north-western part of India.

The traditions and historical records of the Persians are contained in the famous series of writings called the Zend-avesta. These writings are, it is thought, of an age even before the Persian dynasty was established; and it has been shown by the researches of M. Anguetil and Sir W. Jones that there is indeed a great probability of the Zend having been a dialect of the ancient Sanscrit language. In the vocabulary attached to M. Anguetil's great work on the Zend-avesta no less than 60 to 70 per cent. of the words are said to be pure Sanscrit.

As the oldest known language of Persia was Chaldæic, we are again thrown back on Indian sources for the origin of the great book of the ancient Persians. Even the name of the priests of the Persian religion of Zoroaster, Mag or Magi, is of Sanscrit derivation.

The Persians kept up an enormous army, which was spread through all the various provinces and Satrapies, and consisted in great part of paid auxiliaries. In at least the later period of Persian power the Greeks were preferred to all others, and in the time of Cyrus the Younger they composed the flower of the Persian army, and were employed in garrisoning most of the chief cities of Asia Minor.

The description given by Herodotus of the vast army and fleet prepared for the expedition of Xerxes against the Greeks gives us an idea of the extent of the Persian power, and of the wide range of countries and nations over which they held sway. The review held on the Plain of Doriscus was perhaps the greatest military spectacle ever beheld either before or since. Herodotus enumerates no less than 56 different nations, all of them in their national dress and arms. Besides the Persians there were "Medes and Bactrians; Lybians in war chariots with four horses; Arabs on camels; Sagartians, wild huntsmen who employed, instead of the usual weapons of the time, the lasso; the nomadic tribes of Bucharia and Mongolia; Ethiopians in lions' skins, and Indians in cotton robes; Phœnician sailors, and Greeks from Asia Minor." All these and many others were there assembled by the despotic power of the Persian king.

The system of government employed by the Persians, and the constant reports and tributes sent from every province to the central court of the king, were well calculated to bring to it, as to a focus, the curious lore of the various nations who came in contact with or were subdued by them.

The Persians were famed for their knowledge of astronomy and astrology, and were said "to have anciently known the most "wonderful powers of nature, and to have therefore acquired great "fame as magicians and enchanters."

The close relation between the Persian religious traditions and those of the Hindoos is very striking. According to Mohsan, "The best informed Persians, who professed the faith of Hu-shang "as distinguished from that of Zeratusht, believes that the first "monarch of Iran, and, indeed, of the whole world, was Mahabad "(a word apparently Sanscrit), who divided the people into four "orders,—the religious, the military, the commercial, and the "servile, to which he assigned names unquestionably the same as "those now applied to the four primary classes of the Hindoos."

They added, "that he received from the Creator and promul-"gated amongst men *a sacred book in a heavenly language*, to which "the Musselman author gives the *Arabic* title of *Desatir*, or Regula-"tions, but the original name of which he has not mentioned; and "that *fourteen Mahabads* had appeared, or would appear, in human "shapes for the government of this world."

"Now when we know that the Hindoos believe in *fourteen* "*Menus*, or celestial persons with similar functions, the *first* of "whom left a book of *regulations*, or divine ordinances, which they "hold equal to the *Veda*, and the language of which they believe "to be that of the gods, we can hardly doubt that the first corrup-"tion of the purest and oldest religion was the system of *Indian* "theology invented by the *Brahmins* and prevalent in those terri-"tories where the book of Mahabad, or Menu, is at this moment "the standard of all religious and moral duties."

Having established, then, the long and intimate nature of the Persian intercourse with India, let us see how it bears on our more immediate subject.

The works on medicine which are known to exist, and to have been written in Persian, are not very many in number, but they cover a period of time of nearly 400 years. The oldest of them is of the year 1392 A.D., and in it and its successors there are long lists of Arabian authors whose works had been consulted, and also various Indian works.

Greek physicians were in great request at the Persian court, and when the daughter of the Emperor Aurelian was sent in marriage to the Persian monarch, Sapor II., she had a number of Greek physicians in her train. This king founded a new city called Jondisabour in honour of his Queen, and owing to the settlement here of a number of Greek physicians, who had, on account of religious differences, retired into Persia, this city became celebrated as a medical school. Dr. Friend gives the names of these as "Damascius the Syrian, Simplicius of Cilicia, Diogenes of Phænicea, Isidorus of Gaza, and others, the most learned and greatest philosophers of the age." It is thought by some authors that many of the Arabian writers who belonged to the college of Baghdad were educated at Jondisabour.

The district of Jondisabour is even yet one of the most flourishing in Persia, and contains mines which still yield turquoise, salt, lead, copper, antimony, iron, and marble.

During the reign of the Persian king Nooshirwan, his physician Barzoueh made various journeys into India, one of which was specially for the purpose of obtaining copies of Indian literature, and another to obtain medicaments and herbs.

How to account for the strange fact that all schools of medicine which have risen, flourished, and disappeared, have left some trace in historical records, with the exception of that of India, is most difficult, unless under the hypothesis that the language in which the science and philosophy of India was recorded has been almost a sealed book to the world, and is even now quite unintelligible to the people of India itself, generally speaking, and that thus the only way in which the results of the long ages of philosophic study, which unquestionably have had a place in India, have only been known by this dark reflection from the writings of Greek and Arabic writers, which were scattered broadcast over the ancient world. The Greeks, we know, borrowed their science largely from the Egyptians, both in respect to theology and philosophy; and we might, with much profit, pursue the examination of our subject amongst the records of that highly civilized amongst the ancient nations.

Many authors have attempted to show that there is a wonderful resemblance between the Egyptians and the Hindoos, the sculptures on the monuments of the former are most wonderfully like those of India, and the features, dress, and arms are all as like as may be.

Both nations had the various arts of weaving, dyeing, embroidering, working in metals, and the manufacture of glass, and practised them with but little difference in their methods. The fine muslins of India find their counterparts as "woven wind" in the transparent tissues figured on the Egyptian temples. The style of building, the sciences of astronomy, music, and medicine were assiduously cultivated by both nations, and there was direct intercourse between them, perhaps even before historical time begins.

Rameses the Great (III.), called also Sesostris, fitted out not only war ships but merchant vessels for the purpose of trading with India, in B.C. 1235, and Wilkinson in his book on the Ancient Egyptians, tells us that in 2000 B.C. there were no less than 400 ships trading to the Persian Gulf. There is, after all, nothing surprising in this when we remember the fact, which is, however, not generally known, I am afraid, that under the reign of Pharoah Necho, a fleet of his ships safely circumnavigated Africa, from the Red Sea to the Mediterreanean, this being in advance of the celebrated voyage of Diaz and Vasco da Gama by no less than 2100 years.

No less than seven centuries before Thales went to study in Egypt, astronomical calculations were inscribed on the monuments at Thebes, so that we can see how modern by comparison the Greek philosophy appears.

In a note Wilkinson says that "The science of Medicine was "one of the earliest cultivated in Egypt. Athothes, the successor "of Menes of the first dynasty, is said to have written on the "subject, and five papyri on the subject have survived.

"They are of the period of the eighteenth and nineteenth dynasties.

"One known as the Papyrus Ebers, from its discoverer, is attri- "buted to the age of Kherpheres or Bikheres.

"The second, that of Berlin, found in the reign of Usaphais of "the first dynasty, was completed by Senet or Sethenes of the "second line.

"The third, that of the British Museum, contains a receipt said "to have been mysteriously discovered in the reign of Cheops of "the fourth dynasty.

* * * * * * * * * *

"The curatives employed were ointments, drinks, plasters, fumi-

"gations and clysters, and the drugs employed were taken from "vegetables, minerals, and animals.

"Those for each draught were mixed together, pounded, boiled, "and strained through linen.

"The doctors belonged to the sacred class, and were only per-"mitted to practice their own particular branch.

"These were oculists, dentists, those who confined their practice "to diseases of the head, and those again who only attended to "internal diseases; they were paid from the public treasury, and "were compelled, before being permitted to practice, to study the "precepts laid down by their predecessors."

Homer, in the Odyssey, describes Egypt "as a country whose fertile soil produces an infinity of drugs, some salutary and some pernicious, where each physician possesses knowledge above all other men."

The mixing of various drugs and minerals must have produced effects which could not be lost on such observant men as the doctors must, from their training, have been, and it would be absurd to suppose that some, at least, of the simpler chemical decompositions and combinations were not known to them.

The manufacture of glass would seem to have been very ancient amongst the Egyptians, and the insufficiency of the old fable, of its discovery by the fusing of blocks of stone in the fire is quite clear; besides, Egyptian glass has been found which contains potash, and nothing is more probable than that the nitrate of potash, found so plentifully in the soil of India, was imported for this manufacture.

Precious stones or amulets with Sanscrit inscriptions have repeatedly been found in tombs, which must date back to at least B.C. 1400.

In tracing back the history of Chemistry, we constantly find reference to Hermes, Trismegistus, who would seem to be the god Thoth, or Taaut of the Egyptians. The famous inscription of the Emerald table ascribes to him the possession of three parts of the philosophy of the whole world. I have been much struck with the resemblance of this god Taaut with the Menu of the Hindoos, who also was credited with saving from destruction by the flood the three Vedas, which were supposed to contain all that was required for man's direction here below.

There would appear to have been also other Hermes, but if we look at the condition of things which obtained in Egypt when the

Pyramids of Memphis are supposed to have been erected, within 300 years of the supposed date of the deluge, and that the Beni Hassan tombs, about 300 years later, depict the manners and customs of what we cannot help admitting, was a highly civilized nation, we must be struck with the fact that the distance of time between the deluge and the building of these pyramids and tombs is so short, that it might be represented by a comparison of our own date with those of Queen Elizabeth and Henry the Third.

Jackson in his "Antiquities" tells us that, Sanchoniatho states that the most ancient Phœnician records show that letters were invented soon after the dispersion of mankind, by Taaut, the son of Mizor or Misraim, who was the first Egyptian Hermes or Thoth. He went out of Phœnicia, and first, with a colony of Mizrites, settled and reigned in Egypt, and, according to Cicero, gave both laws and letters to the Egyptians.

This Hermes was born in the second generation after the flood, and was not only the inventor of letters and writing, but he is also said to have delineated the sacred characters or symbols of the elements and planets, viz.,—sun, moon, earth, air, fire, water, &c.

These symbols are without doubt of very ancient origin, and Boerhæve in his Theory of Chemistry explains them hieroglyphically as follows:—

+ Denotes anything sharp, gnawing, or corrosive; as vinegar or fire: being supposed to be stuck around with barbed spikes.

⊙ Denotes a perfect immutable simple body, such as gold, which has nothing acrimonious or heterogeneous adhering to it.

☽ Denotes half gold, whose inside, if turned outward, would make it entire gold, as having nothing foreign or corrosive in it; which the alchemists observe of silver.

☿ Denotes the inside to be pure gold, but the outer part of the colour of silver and a corrosive underneath, which, if taken away, would leave it mere gold, and this the adepts affirm of mercury.

♀ Denotes the chief part to be gold; whereto, however, adheres another large, crude, corrosive part, which, if removed, would leave the rest possessed with all the properties of gold, and this the adepts affirm of copper.

♂ Likewise denotes gold at the bottom, but attended with a great proportion of a sharp corrosive, sometimes amounting to a half of the whole, whence half the character expresses acrimony; which, accordingly, both alchemists and physicians observe of iron, and hence that common opinion of the adepts that the aurum vivum, or gold of the philosophers, is contained in iron, and that the universal medicine is rather to be sought in this metal than in gold itself.

♃ Denotes half the matter of tin to be silver, the other a crude corrosive acid, which is accordingly confirmed by the assayers; tin proving almost as fixed as silver in the cupel, and discovering a large quantity of crude sulphur well known to the alchemists.

♄ Denotes almost the whole to be corrosive, but retaining some resemblance with silver, which the artists very well know holds true of lead.

♁ Denotes a chaos—world, or one thing which includes all: this is the character of antimony, wherein is found gold, with plenty of an arsenical corrosive.

The symbols, or at least some of them, may be traced even in the Chinese characters for gold, silver, &c.

The connection of Egypt with India shortly after the Christian era is distinctly indicated in the works of Apuleius. He lived in the early part of the second century after Christ, and was educated first at Carthage, then renowned as a school of literature. He then travelled extensively in Greece, Asia, and Egypt, and became initiated into many religious fraternities and an adept in their mysteries. He was admitted a priest of the order of Æsculapius, and describes the ceremony of the offering of the first-fruits by the priests of Isis, when the navigation opened in spring. The vessel, which was to be set adrift upon the ocean freighted with the offering, was splendidly decorated and covered with hieroglyphics, and after having been "*purified with a lighted torch, an egg, and sulphur,*" was allowed to sail away into the unknown as a sacrifice to procure the safety of the convoy of ships which would soon after start upon their voyage. These rites were of great antiquity.

He speaks, in his first tale, of a witch who, by means of her magic charms, made not only her fellow-countrymen love her, but "*the Indians even,*" and in his initiation into the mysteries of Isis, his robes "bore pictures of Indian serpents."

From what I have now laid before you, in what must necessarily be a very imperfect manner, you will see that there is good reason to believe that in the study of science and philosophy the Indian races were much in advance of the Western nations. The age of science amongst them is very great; we fail utterly in trying to find its beginning, unless we accept the tradition which ascribes to Menu, their great lawgiver (who is supposed to have been Noah), the saving of three out of the four divine books or Vedas from the deluge. This would carry us back to the Antediluvian times for the beginning of our investigations; but without taking any such extreme view of the subject we will find traces of science clearly marked out for us in the history of the Indian races.

The picture of the Brahmins, drawn by Apuleius in the second century, shows how little they have changed in historical times. He says:—

" The Indians are a populous nation of vast extent of territory, " situated far from us to the east, near the reflux of the ocean and " the rising of the sun, under the first beams of the stars, and at " the extreme verge of the earth, beyond the learned Egyptians " and the superstitious Jews and the mercantile Nabathæans; and " the flowing robed Aracidae, and the Ityraeans, poor in crops, and " the Arabians, rich in perfumes.

" Now, I do not so much admire the heaps of ivory of the Indians, " their harvests of pepper, their bales of cinnamon, their tempered " steel, their mines of silver, and their golden streams, nor that " among them, the Ganges, the greatest of all rivers,

" ' Rolls like a monarch on his course, and pours
" ' His eastern waters through a hundred streams,
" ' Mingling with ocean by a hundred mouths,'

" nor that these Indians, though situated at the dawn of day, are " yet of the colour of night, nor that among them, immense dragons " fight with enormous elephants, with parity of danger to their " mutual destruction, for they hold them enwrapped in their slippery " folds, so that the elephants cannot disengage their legs or in any " way extricate themselves from the scaly bonds of the tenacious " dragons. They are forced to seek revenge from the fall of their " own bulk and to crush their captors by the mass of their own " bodies.

" There are amongst them various kinds of inhabitants. I will " rather speak of the marvellous things of men than of those of " nature.

" There is among them a race who know nothing but to tend " cattle, hence they are called neatherds; there are races clever in " trafficking with merchandise, and others stout in fight, whether " with arrows, or hand to hand with swords.

"There is also among them a pre-eminent race called Gymno-
"sophists.

"These I exceedingly admire, for they are men skilled not in
"propagating the vine, nor in grafting trees, nor in tilling the
"ground. They know not how to cultivate the fields, nor to wash
"gold, or to break horses, or to shear or feed sheep or goats.

"What is it, then, they know? One thing instead of all these.
"They *cultivate wisdom*, both the aged professors and the young
"students. Nothing do I so much admire in them as that they
"hate torpor of mind and sloth."

This does not look as if the Indians had been unknown or unappreciated in the second century A.D.

Apuleius is not alone in his respect for the Brahmins. Many of the Greek writers speak of them under the names of Brahmins or Gymnosophists, but always with great respect.

Strabo states, on the authority of Megasthenes (who it will be remembered was Ambassador from Persia, and lived for some years at Palibothra, about 307 B.C.), that "there were two classes of philosophers or priests, the Brachmanes and the Germanes, but the Brachmanes are best esteemed." Towards the close of his account of the "Brachmanes" he says:—

"In many things they agree with the Greeks, for they affirm
"that the world was produced, and is perishable, and that it is
"spherical; that God, governing it as well as framing it, pervades
"the whole; that the principles of all things are various, but water
"is the principle of the construction of the world; that besides the
"four elements there is a fifth, nature—whence heaven and the
"stars; that the earth is placed in the centre of all.

"Such, and many other things are affirmed of reproduction
"and of the soul. Like Plato, they devise fables concerning the
"immortality of the soul, and the judgment in the infernal
"regions, and other similar notions. These things are said of the
"Brachmanes."

Clemens Alexandrinus, after saying that philosophy flourished in ancient times amongst the barbarians, and afterwards was introduced amongst the Greeks, instances the prophets of the Egyptians, the Chaldees of the Assyrians, the Druids of the Gauls (Galatæ), the Samauæans of the Bactrians, the philosophers of the Celts, the Magi of the Persians, and the Gymnosophists of the Indians. The Greek authors distinctly speak of the Brahmins as the chief of the castes or divisions of the Indian people from the time of Megasthenes, who wrote of them in the fourth century B.C.

Sir William Jones, in a paper on the philosophy of the Asiatics, pointed out that "the old philosophers of Europe had some idea of centripetal force, and a principle of universal gravitation," and affirms that "much of the theology and philosophy of our immortal Newton may be found in the Vedas."

"That *most subtle spirit* which he suspected to pervade natural "bodies, and lying concealed in them, to cause attraction and re"pulsion, the emission, reflection and refraction of light, electricity, "calefaction, sensation, and muscular motion, is described by the "Hindus as a *fifth element*, endowed with these very powers; and "the Vedas abound with allusions to a force universally attractive, "which they chiefly ascribe to the sun, thence called 'Aditya, or "the attractor,' a name designed by the mythologists to mean the "child of the goddess Aditi. But the most wonderful passage on "the theory of attractions occurs in the charming allegorical poem "of 'Shi'ri'n and Ferha'd, or the Divine Spirit, and a human soul "disinterestedly pious,' a work which, from the first verse to the "last, is a blaze of religious and poetical fire.

"The whole passage appears to me so curious that I make no "apology for giving you a faithful translation of it:—

"*There is a strong propensity which dances through every atom,* "*and attracts the minutest particle to some peculiar object; search* "*this universe from its base to its summit, from fire to air, from* "*water to earth (the four elements!), from all below the moon to all* "*above the celestial spheres, and thou wilt not find a corpuscle* "*destitute of that natural attractability. The very point of the first* "*thread in this apparently tangled skein is no other than such a* "*principle of attraction, and all principles beside are void of a real* "*basis: from such a propensity arises every motion perceived in* "*heavenly or in terrestrial bodies; it is a disposition to be attracted* "*which taught hard steel to rush from its place and rivet itself on* "*the magnet; it is the same disposition which impels the light straw* "*to attach itself firmly on amber; it is this quality which gives* "*every substance in nature a tendency towards another, and an* "*inclination forcibly directed to a determinate point.*"

In Sir W. Ainslie's Materia Medica of India the opinion of an old Hindoo author is given as to the qualifications required in a physician.

"He must be a person of strict veracity, and of the greatest sobriety and decorum: he ought to be skilled in all the commentaries on the 'Ayur-Veda,' and be otherwise a man of sense and benevolence: his heart must be charitable, his temper calm, and his constant study how to do good.

"Such a man is properly called a good physician, and such a physician ought still daily to improve his mind by an attentive perusal of scientific books.

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"Should death come upon us while under the care of a person of this description, it can only be considered as inevitable fate, and not the consequence of presumptuous ignorance."

The knowledge of the Hindoos may be all said to be contained in their sacred books called the Vedas, which, although perfect as a whole, are actually divided into four parts, each in itself constituting a separate Veda under a special title. These are the Rig-Veda, the Yajur-Veda (white and black), the Sama-Veda, and the Atharva-Veda, or Ayur-Veda. Although the last is admitted to be as a whole not so ancient as the other three, still there are portions of it that are probably as old as any of the others. Even in the oldest epic poems of the Hindoos mention is made of four Vedas as already in existence and as of great antiquity. Sir William Jones estimates the date of its compilation as certainly not after B.C. 1580.

These Vedas are considered by the Hindoos to contain the groundwork of all their philosophy, as well as of their arts and sciences, and they contain treatises on music, medicine, the art of war, and architecture.

Sir William Jones, in referring to the Ayur-Veda, says that, to his astonishment, he found in it an entire Upanishad on the internal parts of the human body, enumerating the nerves, veins, and arteries.

The Ayur-Veda was considered by the Brahmins to be the work of Brahma—by him it was communicated to Dacsha, the Prajapati, and by him, the two Aswins, or sons of Surya—the sun—were instructed in it, and thus became the medical attendants of the gods. A legend that cannot but recall to our mind the Greek myth of the two sons of Æsculapius and their descent from Apollo.

In the case of immortal gods the practice was confined to surgery, in treating the wounds received in the conflicts which were constantly described as occurring amongst the gods themselves, or between the gods and the demons. Of course they performed many miraculous cures, as would be expected from their superhuman character.

Professor Wilson published in the *Oriental Magazine*, in 1823, some notices on early Hindoo Medicine, and he points out that the tradition is, that the above "two Aswins instructed Indra in medical and surgical art, that Indra instructed Dahnwantari; although others make Atreya, Bharadwaja, and Charaka prior to the latter:—Charaka's work, which goes by his name, is extant. Dahnwantari is also styled Kasi-rajah, or Prince of Kasi, or Benares. His disciple was Susruta, his work also exists."

The Ayur-Veda, as the oldest medical writings of the Hindoos are collectively called, was divided into eight divisions. These are described by Professor Wilson as follows:—

"1st. *Salya*.—The art of extracting extraneous substances, violently or accidentally introduced into the body, with the treatment of the inflammation and suppuration thereby induced.

"The word *Salya* means a dart or arrow, and points clearly to the origin of this branch of Hindoo science.

"2nd. *Salakya*.—The treatment of external affections or diseases of the eyes, nose, ears, &c.

"3rd. *Kaya Chikitsa*.—The general application of medicine to the body, or the science of medicine, as opposed to surgery under the two first heads.

"4th. *Bhutavidya*, or demonology: the act of casting out demons, which we may take to mean the treatment of insanity, such as it was.

"5th. *Kaumara bhritya*, or the treatment of the diseases of women and children.

"6th. *Agada*.—The administration of antidotes.

"We do not appreciate this as an eastern nation would when poison was only too common an instrument of ambition or revenge.

"7th. *Rasayana*.—Is chemistry, or perhaps it were better to say alchemy, as its chief aim was the study of combinations of substances mostly metallurgic, with a view of obtaining the universal medicine or elixir which was to give immortal life.

"8th. *Bajikarana*.—Was connected with the means of promoting the increase of the human race."

One of the articles of Hindoo medicine was *Kshara* or alkaline salts,—these are directed to be obtained by burning different substances of vegetable origin, boiling the ashes with five or six times their measure of water and filtering the solution, which was used both internally and externally. Care is enjoined in their use, and emollient applications are to be used if the caustic should occasion great pain.

I have already spoken of the fact of Indian physicians having been at the Court of Persia, and also at that of Haroun al Raschid, and also that the ancient writers on medicine were known to the Arabs of the time of the schools of Baghdad and Cordova. There is no manner of doubt concerning this fact, as in Serapion's works we find Charak actually mentioned by name; under the head *De Mirobalanis* we find "*Et Xarch indus dixit;*" and again, in another section "*Xarcha indus;*" there being no corresponding sound to che in Arabic, there is a slight change in the name, but it is quite clear what it is intended for. In Avicenna, again, we find reference to "Scirak indum." Rhazes, again, who was previous to Avicenna, has "*Inquit Scarac indianus,*" and again "*Dixit Sarac;*" in another place an Indian author is quoted, who has not as yet been traced, "*Sindifar,*" or, as it is in another place, "*Sindichar indianus.*"

Professor Wilson, in a notice on the medical science of the Hindoos, published in the *Oriental Magazine,* examines into the distinctive qualities of the various sorts of leeches, and shows that the description given in Avicenna, in the section "De Sanguisugis," is almost identical with the Hindoo author's description of the twelve sorts of leeches, in distinguishing the appearance and properties of the various sorts.

That this is more than a mere coincidence is clear from the fact that Avicenna says "*Indi dixerunt.*"

I do not think it will be seriously disputed that the Arabs had access to the Hindoo works of and before their time, and we will find, if we carefully examine the subject, that the science of medicine as distinguished from surgery, and of chemistry as a part of that science of medicine, was much more ancient than we have been prepared to admit.

It would be incredible to believe that amongst a people so observant and highly cultured as the Brahmins must have been, that medicine and the changes occurring in mixtures of various substances should have been unstudied, and there is no doubt that this subject was far from being neglected by them.

Many natural productions of the country, such as nitrate of potash, borax, carbonates and sulphate of soda, sulphate of iron, alum, common salt, and sulphur, could scarcely escape the notice of even ordinary men; but Dr. Ainslie has shown, from the evidence of old Indian medical works, that they were not only acquainted with ammonia (which they made by distilling salammoniac one part, and chalk two parts), but that they prepared sulphuric acid by burning sulphur and nitre together in earthen pots, calling it *Gunduk Ka Attar*, or "attar of sulphur." Nitric acid, which was prepared, not by the process described by Geber, but by mixing saltpetre, alum, and a portion of a liquor obtained by spreading cloths over the common gram plant, and leaving them exposed to the dew, when they were found to absorb the acid salt so abundantly secreted by the plant on the surface of its leaves, and which, when examined by Vauquelin, was found to contain both oxalic and acetic acids.

Muriatic acid was also made by distilling alum and common salt, dried and pounded with the above acid liquor.

Arsenic was used by them for the cure of palsy, and also for venereal diseases, and is still used by them for this purpose, and in intermittent fevers.

It would occupy too much time to go further into this subject at the present time, but there are many chemical compounds which are still made and sold in the Indian bazaars which have been used from time immemorial, and which require a knowledge of chemical manipulation in the arts of subliming, distilling, &c.

Mr. Rodwell says, "that the distillation of cinnabar with iron, described by Dioscorides, is the first crude example of distillation, which afterwards became a principal operation among the alchemists and chemists for separating the volatile from the fixed."

That this is an assumption which has no foundation in fact is evident, when we find in the Institutes of Menu many enactments against the drinking of distilled spirits, and these made of various kinds and distilled from molasses (or sugar-cane juice), rice, and the madhuca flowers.

"A soldier or merchant drinking arak, mead, or rum are to be considered offenders in the highest degree," and "for drinking spirits are to be branded on the forehead with a vintner's flag," rather a summary way of treating a drunkard, and one which would indicate that the ill effects of over-indulgence in spirituous liquors had been long known, when such severe enactments were made against it.

The method of distilling described by Mr. KEIT in the Asiatic

Researches, vol. 1, is so simple that it is almost certain that it was employed in very ancient times for the purpose of distilling spirits, and also attars of various sorts, which, from time immemorial, would seem to have been a special production of India.

"The body of the still is a common large unglazed earthen water "jar, nearly globular, of about 25 inches diameter at the widest "part of it, and 22 inches deep to the neck, which neck rises 2 "inches more, and is 11 inches wide in the opening; this was filled "about a half with fermented mâhwah flowers, which swam about "in the liquor to be distilled.

"This jar they placed in a furnace, not the most artificial, though "not seemingly ill adapted to give a great heat with but very little "fuel. This they made by digging a round hole in the ground, "about 20 inches wide and full 3 feet deep, cutting an opening in "the front sloping down to the bottom, perpendicular at the sides, "about 9 inches wide and about 15 inches long, reckoning from the "edge of the circle: this is to serve to throw in the wood and to "allow a passage for the air; at the other side a small opening "about 4 inches by 3 inches is made to serve as an outlet for the "smoke, the bottom of the hole thus made was rounded like a cup.

"The jar was placed in this as far as it would go, and banked "up with clay all round to about a fifth of its height, except at the "two openings, when all was completed so far as the furnace was "concerned.

"Fully one-third of the still or jar was exposed to the heat when "the fire was lighted; the fuel was at least 2 feet from the bottom "of the jar.

"On to this jar there was now fitted what is called an adkur, "this being made of two earthen pans with their bottoms turned "towards each other, and a hole of about 4 inches diameter in the "middle of each of them, the lower of these pans fitted the hole "in the jar, and was luted with clay, the upper was luted to the "lower one, and had a diameter of about 14 inches, the juncture "formed a neck of about 3 inches, the upper pan was about 4 inches "deep, with a rim round the central hole, this formed a gutter, "and by means of a hollow bamboo luted to this, the spirit, as it "condensed, ran off into the receiver.

"The arrangement was now completed by luting on a small "copper pot or vessel about 5 inches deep, 8 inches wide at mouth, "and about 10 inches at bottom, with its mouth downwards.

"The cooler was formed by placing on a support at the back of "the furnace an earthen vessel containing a few gallons of water, "from which, by means of a bamboo tube, the water was allowed "to run on to the centre of the copper pot, from where it collected "in the clay saucer, and ran off by a small hole and bamboo tube "for use again.

"In about three hours' time from lighting the fire, they draw "off fully fifteen bottles of spirits."

Comparing this simple form of apparatus with those described by Geber, we must admit that there is no doubt of the earlier date of this simple apparatus; and, as we have seen, distilled spirit is expressly mentioned in the Institutes of Menu, we are bound to admit that distillation was in use long ere the Arabian times and that of Dioscorides.

Many such examples might be examined, but I will take one for illustration—that of the manufacture of common salt.

Let us take this manufacture as a typical one.

We find in Jackson's Antiquities and Chronology of the Chinese that, 2500 B.C., Shin-nong invented the method of obtaining salt from sea-water. He also gets credit for having composed books on medicine.

In George Agricola's De Re Metallica (1561) there is a curious set of woodcuts representing the manufacture of salt, and in the first, in which the whole process of evaporating sea-water by the sun's rays is shown most completely from the raising of the sluices to allow the water to flow into the various evaporating ponds, to the packing of the finished salt in barrels—it is a curious fact that the trees which are introduced are *palms*, and the figure in the distance is dressed in *Oriental costume*, while even the ship seems to partake of this character.

A more advanced state of things is shown in the third drawing of the 12th book, where a pan is shown, made of iron plates riveted together so as to form a flat sheet, which forms the bottom of the pan, of which the sides are composed of thick wood, strengthened with plates of iron at the corners.

The bottom of the pan has a series of iron eyes or loops, and these, when it is fixed over its furnace, are attached to iron rods, which are hung from a network of wooden bars, so that the whole bottom of the pan is supported securely at a considerable number of points.

The furnace is very simple, being simply a wall surrounding an oblong space, a little smaller than the pan, so that the sides of the latter may rest on the walls all round, except for a small space in front where the fuel is introduced, which apparently burns on the ground alone.

The method of manufacturing salt in Japan is almost identical with that figured in Agricola. There is the same arrangement of salt garden or series of ponds and ditches, and the dirty salts mixed with sand are again lixiviated, and the filtered liquid is boiled down in curiously formed pans or boilers.

Of these there are two chief forms, the first being a tank or pan formed of large pieces of slate, with the joints made with clay, and surrounded with a mud wall. The whole is covered with an arch or vault and is filled with the brine, which is then evaporated by surface heat, the fire being placed at one end and the flue at the other.

The other form is very curious and interesting, and is almost identical in its principle of construction with the pan I have referred to as figured in Agricola, only in this case the materials are very different, being, instead of wood and iron, nothing more than clay or mud.

It was described officially by the Japanese, in their publications at the Philadelphia Exhibition in 1876. The Japanese description of this apparatus is highly interesting. It is as follows:—

A low wall is built, enclosing a space of about 13 feet by 9 feet, the bottom forming a kind of prismatical depression, 3 feet deep in the centre line. An ashpit, 3 feet deep, is then excavated, starting from the front wall, and extending about 4 feet into this depression at its deepest place; it communicates with the outside by a channel sloping gradually upwards, and passing underneath the front wall. The ashpit is covered by a clay vault, with holes in its sides, so as to establish a communication between the ashpit and the hollow space under the pan. This vault is used as a fire grate, the fuel (brown coal and small wood) being inserted by the fire-door in the front wall. The air-draught necessary for burning the fuel enters partly by the fire-door, partly through the ashpit and the openings left in the vaulted grate. Through these same openings the ashes and cinders are from time to time pushed down into the ashpit, for which purpose small openings are left in the side-wall of the furnace, through which the rakes may be introduced. A passage in the back wall supporting the pan leads off the products of combustion and the hot air into a short flue, sloping upwards, and ending in a short vertical chimney. At the lower part some iron kettles are placed in the flue for the purpose of heating the lye before it is ladled into the evaporating pan.

With reference to the pan, it is made in a way that requires a great deal of skill and practice. In the first place, beams reaching from the one side to the other are laid on the top of the furnace walls, and are covered with wooden boards, forming a temporary floor. Two or three feet above this floor a strong horizontal network of poles of wood sustains a number of straw ropes, with iron hooks hanging down, and of such a length that the hooks nearly touch the wooden floor. The floor is thereupon covered with a mixture of clay and small stones, 4 to 5 inches thick, the workman being careful to incrustate the iron hooks into this material. It is allowed to dry gradually, and when considered sufficiently hardened, the wooden beams and flooring are removed with the necessary precautions. The bottom of the pan remains suspended by means of the ropes. The open spaces left all round between the bottom and the top of the furnace walls are then filled up, and the border of the pan, 9 inches to 10 inches high, is made of a similar mixture. It is said that this extraordinary construction lasts from 40 to 50 days when well made, and that it can be filled 16 times in 24 hours, with an average of 500 litres of concentrated lye at each filling; but the quantity depends upon the weather, and is less in winter than in summer. During the cold season one pan yields 140 litres (of salt) each time it is filled, and in the hot season from 190 to 210 litres. The average consumpt of fuel is said to be 1500 kilos. in 24 hours.

In Persia, near Ballakhan, salt is still made, and has been made from time immemorial, in a very primitive way, which is described by Bellen, in his description of his journey in 1872 from the Indus to the Tigris, as follows:—

"For several miles our road led over a succession of salt pits and "ovens, and lying about we found several samples of the alimentary "salt prepared here from the soil. It was in fine white granules "massed together in the form of the earthen vessel in which the "salt had been evaporated. The process of collecting the salt is "very rough and simple. A conical pit or basin, 7 or 8 feet deep "and about 12 feet in diameter is dug, and around it are excavated "a succession of smaller pits, each about 2 feet diameter by 1½ feet "deep. On one side of the large pit is a deep excavation, to which "the descent from the pit is by a sloping bank. In this excavation "is a domed oven with a couple of fireplaces. At a little distance "off are the piles of earth scraped from the surface and ready for "treatment. And, lastly, circling round each pit is a small water-"cut led off from a larger stream running along the line of pits.

"Such is the machinery. The process is simply this:—A shovel- "ful of earth is taken from the heap and washed in the basins (a "shovelful to each) circling the pit.

"The liquor from these is, whilst yet turbid, run into the great "central pit, by breaking away a channel for it with the fingers. "The channel is then closed with a dab of clay, and a fresh lot of "earth washed, and the liquor run off as before; and so on till the "pit is nearly full of brine. This is allowed to stand till the liquor "clears. It is then ladled out into earthen jars, set on the fire and "boiled to evaporation successively, till the jar is filled with a cake "of granular salt. The jars are then broken, and the mass of salt "(which retains its shape) is ready for conveyance to market.

"Large quantities of this salt are used by the nomad population, "and a good deal is taken to Kandahar. The quantity turned out "here must annually be very great. The salt pits extend over at "least ten miles of the country we traversed, and we certainly saw "some thousands of pits."

From what I have laid before you, it will be seen that I am strongly of opinion that we must go far beyond the time of Geber or the Arabian school for the origin of our science. The study of the question of its antiquity leads up to such remote times that there is little probability of any date being assigned to its beginning, and to some it may appear but a waste of time to indulge in researches upon the subject; but it has a fascination peculiar to itself, and, in addition, brings before our minds so many phases in the philosophical thought of the world, that it will no doubt long continue to exercise the minds and attract the attention of chemists.

In the course of my own study of the subject, I have felt much dissatisfied with the derivation of the name chemistry or alchemy, as it is given in all works to which I have had access. It is said to be derived from a word meaning dark, hidden, black, and from the ancient name for Egypt, but to my own mind this is an unsatisfactory explanation, and seeking for another more consonant with the character of the science, I think I have found it in quite a different direction.

It is well known that in the old Hindoo philosophy there were recognized five elementary bodies or rather types. These were Water, Fire, Ether, Earth, and Air, and the system of Menu, of which the antiquity is enormous, recognizes as the greatest conception of the universe—

1st, God.
2nd, Mind.
3rd, Consciousness.
4th, Matras.
5th, Elements.

(matras being the invisible types of the visible atoms which compose the five elements previously named—viz., Water, Fire, Ether, Earth, and Air).

Now, these elements, with the sun and moon, composed the attributes of the dual deity Iswara and Isi, representing the male and female natural powers, and, applying this to the famous Pythagorean triangle, we find that the upright symbol or male, which was the number or power 3, when combined with the female prostrate symbol, which was the number or power 4, gives a product in the Hypotenuse of 5, which is the number of the typical elements of the oldest known Hindoo philosophy. It is also the product of the first male and female numbers, and was anciently called the number of the world—repeated anyhow by an odd multiple it always reappears.

If now we consider chemistry as that science which has to deal with the changes and combinations of the five elements, and if we call it—

The science of the five parts or elements, should we not, when we find that the Arabic word for five is *khams*, rather refer the name of our science to this word khams, and read it as

Al-Khams,
The five-part science?

I am inclined, however, to go yet a step further, and remembering that the *fifth* element or Ether of the most ancient Hindoo philosophy, was in reality an expression for active force, or, that emanating from the central sun caused the natural phenomena of attraction and repulsion, the emission and refraction of light, and other sensible changes of condition, would read the compound word

Al-Khamis
(The fifth),

as the grand and simple title of our ancient science, meaning

The force—

that which causes the changes in the elementary types and their combinations—than which no more descriptive title could be assigned to it, even in the present enlightened age.

V.—*On the Present Position of Scientific and Technical Education in Germany.* By E. M. DIXON, B.Sc., Secretary of the Society, and Head Master of Allan Glen's Institution.

[Read before the Society, December 17, 1879.]

MR. PRESIDENT AND GENTLEMEN,

Referring to the *Proceedings* of this Society, I find that in recent years two papers have been brought forward by Mr. David Sandeman and the late Dr. Bryce respectively, upon portions of the educational system of Germany. If I may presume to criticise these papers in any way, I will say that it does not appear to have entered into the object of either of these gentlemen to explain the relation in which the schools or institutions that he described stand to the general educational system of the country; and I therefore incline to think that, while these papers are excellent as descriptions of certain schools *per se*, they may possibly have appeared to some, who are unacquainted with the high standard of education in Germany, as one-sided and overdrawn pictures of a class of schools that would be useless or impracticable in this country. However that may be, it seems to me that a brief description of, at least, the leading features of the school-system of Germany will not be out of place in the present paper; but that, in fact, such a description will throw important light upon the scientific and technical institutions that are to form the main part of my theme.

Further, the adoption of this method of presenting my subject is supported by the fact, that it is necessary to have an acquaintance with the entire educational system of a foreign country before we can judge correctly regarding the introduction of any particular school from that country into our own. It is impossible simply to transplant a foreign school to English soil, for no school will flourish in this country that does not fit properly into our general school-system. The introduction of a foreign school must, therefore, necessarily be accompanied with modifications, and these modifications must be more or less fundamental, according to the relation in which the general school-system of the country from which we borrow stands to the general school-system of our own country.

It is, I believe, very important that the principles I have just stated, with respect to the transference of schools from one country to another, should be fully recognized at the present time. It seems to me very manifest that the people of this country are on the point of awakening to the fact that something must be done to raise the standard of our education in the direction of pure and applied science; and, if we go to Germany in particular for information as to the course we should pursue, it must not be in the spirit of mere imitators, but in the spirit of intelligent adapters. I cannot well conceive, for instance, a greater mistake that could be committed than to attempt the introduction into this country at the present moment of the Polytechnicum or Technical High School of Germany. That is an institution which, as I shall presently show, is beyond anything as yet dreamt of in this country, both as regards the character of its courses of instruction and as regards the extraordinary completeness of its appliances. I confess it is from the fact that its courses of instruction are so very high that I would despair of introducing it successfully at present into this country. In Germany that school has a position with respect to Secondary Education that it certainly could not have here at present, and which it probably would not have even for many years to come. There it has feeders that supply it with pupils capable of entering at once upon high professional courses of instruction; in this country, it must be admitted, the supply of such pupils would be very limited at present. A Technical High School would, therefore, for the present at least, be a failure in this country; for, either it would be attended by a mere handful of students, or it would have to reduce the standard of its teaching and become a Technical High School only in name.

While, however, I think it necessary to say that the improvement of our school system can be made neither in whole nor in part by the mere imitation of German models, I believe, on the other hand, that many valuable suggestions in that direction may be got from the study of the German schools and universities. Germany offers us also what is, perhaps, more important than a lesson in the technicalities of school arrangements—she offers us the example of a people that still believes, with Lord Bacon, that "knowledge is power," and that, in the practical business of life, "expert men can execute and perhaps judge of parti-"culars one by one, but the general counsels and the plots and "marshalling of affairs come best from those that are learned." Germany is in no fear, for instance, of making her military officers pedants, by giving them a liberal general education as the foundation of their professional training; on the contrary, she has no faith in professional training of any kind apart from a good preliminary general education. It is from this motive that she bars the doors of her highest professional schools—her universities and technical high schools—against all who present themselves with what is considered an insufficient amount of general education. For instance, no student is admitted to matriculation in a German university who is unable to produce a certificate from the authorities of a public gymnasium or classical school, to the effect that he has mastered the subjects taught in it; and, as we shall see, the regularly-matriculated students of the German universities constitute at least *nine-tenths* of the total number of their students.

There are some points connected with the admission of students to the universities that merit a little notice, as through them we get a somewhat valuable glimpse into the position of technical education at the present moment. As I have said, no young man is admitted to matriculation—that is, to official recognition—who has not gone either through the full curriculum of a public gymnasium, or can show that he has attended a private school that stands educationally on a level with a gymnasium. Now, the curriculum of a gymnasium is so extensive, that youths are scarcely ever able to present themselves for the statutory examination at the end of it, before their 18th, 19th, or 20th year. Moreover, fully one-half of their time in the gymnasium is devoted to the study of Latin and Greek. The consequence is that those who proceed to the universities enter them, as we should think, very late in life, and with an amount of classical knowledge that is out of proportion to the requirements of such professions at least as law and medicine. The fact that the universities will not recognize the attendance of a youth who has not passed through such a course of education testifies to the prevailing estimate of the classical languages as a means of general culture, and to the prevailing belief that professional training is, strictly speaking, impossible, unless it is preceded by a liberal general education.

German education is now, however, beginning to feel the modifying influences of science, and of the industrial requirements of our time; and, to the great regret of many, secondary schools have of late been instituted, in which the study of the classical languages is either very much curtailed or altogether abolished, the time that is thereby set free being devoted to the study of the modern languages and science. Although the curriculum of these schools is quite as extensive as that of the classical schools, and though the amount of education acquired by the generality of youths who pass through these schools will compare favourably with that acquired by the pupils of the latter, the non-classical schools, as I may call them for the moment, are not recognized by the universities, and such of their pupils as desire further instruction must betake themselves to the technical high schools.

I believe, however, that it may be safely asserted that the admission to the universities of the pupils of all the higher or secondary schools is only a question of time, and it is generally expected in Germany that this concession will very shortly be made with regard to the medical profession at least. Meanwhile, there is no doubt that the degree of monopoly which the universities and the classical high schools enjoy is, to some extent, justified by their advantages over the newer institutions in their relatively greater maturity of experience, and in the larger share of popular favour with which they are regarded. Still, as I have said, there are very decided symptoms of coming changes; and of these, perhaps, not the least significant is the discussion which took place last year in the Prussian Chamber of Deputies on the question of technical instruction.

Of that discussion I can say little more here than that it terminated in three important measures—one for improving the management of the technical high schools; another for the instituting of an additional feeder for the same, in the form of a secondary school, in which neither Latin nor Greek should be taught; and a third for the instituting of what, I believe, will eventually prove to be one of the most important schools in Germany—viz., a technical middle school, from the curriculum of which also the classical languages are to be excluded. To any person who knows the position of classical learning in Germany it is needless to say that the discussion to which I refer was full of testimony to the advantages to be derived from a thorough study of the ancient languages and literatures; but at the same time there were not a few speakers who contended that all the benefits in the way of mental culture which are to be derived from the study of the classical languages can be secured by an equally thorough study of modern languages. In any case, it was agreed that the development of technical instruction is a necessity of the times; and that, for the higher middle and upper classes of German society, at least, such development meant the extension of the

Technical High School, and of a set of non-classical schools that should work in connection with it. To the Technical Middle School I shall refer particularly by-and-by; but, before passing from the point before us, I wish to say, that the discussion to which I refer brought out very clearly the opinion of the Prussian Government with respect to the necessity of supplying not only the upper, but also the middle and lower classes of the people with the means of technical instruction. It was, I may say, the unanimous opinion of the speakers who represented the Government, that all that has yet been done for technical education in Germany is but the beginning of what must eventually be done in that direction.

Such is the best general sketch I can give within the time at my disposal of the Higher or Secondary Schools of Germany. You will have gathered from it that the universities and the technical high schools, which may be said to stand on the same level, are intimately connected with the secondary schools, so intimately, indeed, that pupils coming from the middle or from the elementary schools are not officially recognized by them in any way. You will also have gathered that there are three kinds of secondary schools, one called the *Gymnasium*, and devoted principally to the study of the Greek and Latin languages; another called the *Realschule*, and from which the study of Greek is altogether excluded, while the study of Latin is very much curtailed; and a third called the *Höhere Gewerbeschule*, and from which the study of the classical languages is altogether excluded. It has also been stated that, while the pupils of the classical schools have the privilege of proceeding to the universities, or to the technical high schools, as they may think fit, the pupils of the *Realschulen* and the *Höhere Gewerbeschulen* are allowed only to proceed to the technical high schools. Finally, I have expressed my opinion that the privilege connected with the classical schools is not likely to last long in the face of the change that is gradually taking place in public opinion with respect to the educative power of other branches of learning than the classical languages, and in face of the felt necessity for diffusing technical instruction among all ranks of the people. At present, I may add, there are in Prussia, with a population of nearly 26 millions, about 300 public secondary or higher schools, attended by very nearly 100,000 boys; and the estimation in which the classical schools are still held is shown by the fact that these form rather more than *two-thirds* of the total number.

I now turn to the Universities, which, as I have already shown, assume that their students have received a good general education before admission, and that they are seeking in the university instruction of a professional character. I have spoken of the conditions under which the universities admit students who wish their attendance to count as a qualification for a degree, but I must now add that all students are freely admitted if their object simply is to hear lectures, or otherwise obtain information on special subjects. The number of students who are seeking information without a view to graduation is, however, in most universities, very much less than that of the regularly-matriculated students. For instance, taking the students who attended the universities during the summer session of this present year, I find that out of a total of 22,790 the number of matriculated students was 20,769—*i.e.*, the matriculated students formed approximately *nine-tenths* of the total number.

After a student has passed through the ordeal of matriculation, his next step is to have his name placed upon the register of the particular faculty in which he means to graduate, and of which faculties there are usually four—viz., theology, law, medicine, and philosophy. In no faculty does the course of lectures extend over less than three years, and in medicine it extends over at least four years. A student does not require to hear his entire course of lectures in the particular university in which he may matriculate, but he may hear lectures in his faculty in any German university —the essential thing for graduation being that he complete his course and stand his final examination.

As regards the teaching staff of the German universities there are not a few peculiarities. One of these is the great number of teachers in proportion to the number of students. For instance, there are at present in the University of Berlin 230 teachers to 4463 students; in Bonn there are 101 teachers to 1078 students; in Leipzic 168 teachers to 3016 students, and so on. The explanation lies in the fact that every faculty counts not only its *ordinary* professors, who are all experienced and not unfrequently somewhat aged men, but it counts *extraordinary* professors, who are, as a rule, to become the successors of the ordinary professors, and who, meanwhile, are in a sense their assistants. Besides these two classes of teachers we have the generally somewhat numerous one of the *privat-docenten*, who may be described as young men who have shown marked skill or attainments in some special department, and are therefore allowed to deliver lectures to such students as they can attract. A privat-docent may even compete with one of the professors by lecturing upon the same subjects; but, as a rule, the ordinary and the extraordinary professors come to an arrangement with the privat-docenten, whereby such collision is avoided and their common subject is divided amongst them, and so is more exhaustively treated. Although the privat-docent is in some measure a competitor, he generally finds himself treated with courteous consideration by the ordinary professors, and if he does not care to occupy himself in other ways, he lives in hope that in the fulness of time he may rise to the position of an extraordinary and thence to that of an ordinary professor.

From these facts it may be inferred that, in the larger universities at least, there can scarcely be a subject, or even a minute branch of a subject, in which a student can be interested, and in which he cannot obtain public instruction of the highest quality. One illustration, however, may not be out of place; and, because it is closely connected with the subject of this paper, I will take the case of physics, as it is being taught during the present winter session in Berlin. Professor Helmholtz is delivering two courses of lectures, one upon Experimental Physics, and another on Mathematical Physics, and in the latter of which he holds himself at liberty to employ freely the Differential and Integral Calculus; Professor Kirchof is lecturing on Mathematical Optics, Privat-docent Neesen is lecturing on the Mechanical Theory of Heat; Privat-docent Aron, on the Theory of Electricity; and Privat-docent Glan is delivering a short course introductory to Theoretical Physics, besides going over a regular course of practical exercises in the use of Physical Apparatus for the benefit of teachers for the secondary schools. The celebrated Physical Laboratory, which has been recently built under the direction of Professor Helmholtz, and the positive magnificence of which I cannot undertake at present to describe, is open daily to students who are capable of carrying out original research. As it may be interesting to many members of this Society to hear what arrangements exist for the teaching of Chemistry, I may say briefly that, during the present winter, 12 teachers are delivering courses of lectures in the University of Berlin, on, I believe I may say, very nearly all the departments of the science, including its most theoretical as well as its most practical departments. As evidence of the completeness of the appliances for the delivery of so many and so varied courses of lectures, I may also add that I have it on the authority of Professor Hofmann, that each lecturer has a special set of apparatus for his work. The medical portion of our Society will also be gratified to know that, in Berlin, 81 teachers are at present striving to communicate the details of the healing art.

From these, and from similar facts that might be quoted at great length, I think we may fairly conclude that Natural Science, like the other departments of knowledge, is brought, by means of the universities, within the reach of, at least, the upper middle and higher classes of the German people, with a degree of completeness that is little short of astonishing to us. Notwithstanding that fact, however, it has been felt that, for the benefit of young men belonging to the classes mentioned, and who intend devoting themselves to manufacturing, or to such technical pursuits as those of the civil engineer, the mechanical engineer, the architect, the metallurgist, the shipbuilder, and the like, it is desirable that courses of instruction should be provided, in which science is taught with constant reference to its applications in these directions. Hence has arisen of late the Polytechnicum or Technical High School, and which may be fairly characterized as a modern university for the teaching of applied science.

It will, I believe, be sufficient for the objects of this paper if I convey to you a clear idea of the leading features of the Technical High School; and, as it very much resembles the University, my description need not be long. Like the University, it makes stringent demands upon the young men, who seek from it not only technical instruction, but also an official diploma at the end of their studies. German students must have attended one or other of the higher schools, and, after going through the entire curriculum of the school, have passed successfully the statutory examination at the end of their course. Foreigners, and pupils generally, not educated where the German higher schools exist, must pass an entrance examination before they can be admitted as officially recognized students. If, however, the object of a young man is simply to obtain instruction in some special subjects, and not to acquire an official diploma, he is as freely admitted as he would be in the universities. The arrangements regarding the freedom of the student to pass from one Polytechnicum to another, and the requirements regarding the granting of diplomas entirely agree with the arrangements on these heads in the universities. As regards general management, the tendency is to assimilate the

Polytechnicum closely to the University, and the teaching staff is also similarly constituted in both. There are the same facilities in both for obtaining the best instruction in the subjects that come within their respective spheres; and, in fact, it may be said, in a word, that the only material difference which exists between them lies in the professions for which they respectively qualify their students.

To this general description I will add a few particulars regarding the courses of instruction in the Technical High School of Aix-la-Chapelle, which is the most recent, though not the largest, specimen of the institution in question.

The professions included in the syllabus of this school are those of architect, civil engineer, mechanical engineer, metallurgist, chemist, and land-surveyor. There are also courses of instruction for teachers in the non-classical secondary schools. The courses of instruction for architects, civil engineers, mechanical engineers, and metallurgists, extend over 4 years, the other courses last 3 years. Instruction is given partly by lectures, and partly by practical exercises in the various laboratories, museums, and designing-rooms of the school. A student is understood to be at work in these places when not engaged in hearing lectures. There are four laboratories for the practical study of physics, analytical chemistry, technical chemistry, and metallurgy respectively. The various models, drawings, apparatus, preparations, and specimens employed for the illustration of lectures form 18 collections. There is also a library and a reading-room in connection with it. The teaching staff consists of 23 ordinary professors, 7 extraordinary professors, and 14 assistants.

I may add that there are in Germany, strictly speaking, 8 technical high schools, as against 21 universities, and that there are, approximately, 6,000 students in the former, as against 22,000 students in the latter. Thus we see that, as yet, the great majority of the best educated men of Germany receive their general education in the classical schools of the country and their professional education in the universities; while somewhat less than a fourth of the total number of those who take full advantage of the highest educational institutions of the country, pass through what we may call the non-classical schools, and thence through the technical high schools. We have to remember, however, that the industries of the country have the full benefit of this fourth, while the extent to which the national industries are directly benefited by the classical schools and the universities, is by no means represented by the total number of young men who pass through these institutions. We can, indeed, only form an approximate estimate of the proportion of university men who bring their high education to bear directly upon the national industries, but I incline to think that it is very small. If we deduct from the total number of students in the universities last session 2700, 5400, and 4000, as representing the faculties of Theology, Law, and Medicine, respectively, we have left rather less than 8000; and this number has yet to be very considerably reduced on account of the young men preparing for the office of teachers in the secondary schools, as well as on account of the rather numerous class to whom the university is a time-honoured lounge, and an arena for practising the use of the broadsword. Not to speak, then, of the growing tendency to development in the way of technical education, I believe it may be safely said that, at the present moment, the technical high schools very much surpass the universities in contributing directly to the furtherance of the national industries.

In the secondary schools, universities, and technical high schools, which I have now described as fully as is, perhaps, consistent with the scope of the present paper, the higher and upper middle classes of the German people find their general and professional education, and we have now to see what provision exists for bringing scientific and technical education within the reach of those in a humbler sphere of life. Unfortunately, however, for simplicity of exposition, the institutions that must now be brought under notice are not characterized by the thorough and uniform plan of organization that prevails in the higher institutions that we have been considering; and this part of my subject must therefore be treated in a somewhat fragmentary manner, as I shall have now to describe individual specimens of schools rather than explain a school system. There are, however, a few general remarks that may be, I think, profitably made by way of introduction to the few details I have to present.

There is no doubt that the amount of education, whether general or professional, that any given youth receives is, as a rule, determined chiefly by the pecuniary circumstances of his parents. In Germany the earliest age at which boys can leave school is 14 years, and it is said that fully *nine-tenths* of all the boys are withdrawn from school at that age on account of the pecuniary circumstances of their parents. The elementary schools of the country are consequently very numerous and very cheap, or, indeed, altogether free. In Berlin all these schools are free. They are also, it should be said, excellent schools of their kind—the teaching in them being, so far as it goes, very thorough. Drawing, elementary mathematics, and a few elementary notions of physical science, are all in the form of scientific or technical instruction that can well be introduced into the curriculum of such schools, and consequently it is in the evening-school that the working population is, as a rule, to receive the technical instruction it is destined ever to enjoy. Fortunately, however, there are many exceptions to this rule, for it is not an uncommon thing to find young men who had to leave the elementary school at 14 years of age, and who have, since learning their trade, saved a little money, which they are willing to spend in acquiring technical instruction. For the encouragement of such cases it has been considered necessary to institute, in accordance as far as possible with local wants, technical schools, that give during a greater or less part of the year courses of instruction bearing upon one or more trades, and suited as far as possible to the comparatively slender education of their pupils. These schools exist under a variety of forms in different parts of Germany, and I shall again refer to them.

Again, many parents belonging, for the most part, to the lower middle class, make great sacrifices to place their sons in the position with respect to education that enables them to earn the highly-coveted privilege of spending but one year in the army. This privilege is connected with the middle and the secondary, but not with the elementary schools, and it can be claimed only by youths who have attained to a clearly-defined position in these schools. Of that position it is enough to say here that, as a rule, it is beyond the reach of a lad under 16 years of age. One effect of the regulations regarding military service, therefore, is to cause a very large number of boys to remain at school till about their sixteenth year, and very little longer; and thus another tolerably well-defined class of pupils arises that is considered to be sufficiently numerous and distinct to call for a class of technical schools specially suited to its circumstances. Hence have arisen various schools in different parts of Germany, bearing a variety of names, and organized in a variety of ways, and to which also I shall presently refer in some slight detail.

From these remarks it will be seen that, from pecuniary and military circumstances together, there are in Germany three very well-defined classes of pupils whose educational requirements, in general subjects at least, are very thoroughly met by the secondary, the middle, and the elementary schools respectively. The technical education of the highest class has also, as we have seen, been very thoroughly provided for in the universities and technical high schools; and, from the statements I have now made, it will be evident that some progress, at least, has been made in the way of supplying technical education to the classes below the highest. I believe it is safe to say that nothing but pecuniary means are wanting on the part of the German Governments towards the establishing of technical schools on an extensive scale and upon a uniform plan of organization; and I am satisfied that, if Germany could afford to reduce her great military expenditure, we should soon witness an exhibition of her faith in the value of technical education for all classes of the people.

Now, although it is difficult to speak about the views that prevail in Germany regarding those technical schools, which as yet exist rather in idea than in fact, I think there are one or two propositions on the subject that may be said to be looked upon as axiomatic. One of these is, that the less general education a youth has received, the less power of abstract thinking does he, as a rule, possess, and the greater the necessity of teaching technical subjects to him through his practical experience of his trade. Hence it is, I believe, that efforts have been and are still being made to discover the most convenient and, at the same time, the most efficient means of linking together the instruction of the technical school and the experience already gained or to be gained in the workshop. Another proposition that seems to be regarded as axiomatic is, that a youth can only learn his trade properly when he is surrounded by all the tools and appliances actually used in his trade, and with all its processes continually under his view. And a third axiom, I may venture to say is, that the time required by any given youth to learn his trade depends very much upon whether he receives systematic teaching in its processes and in the construction and proper use of its tools, or whether he is allowed to pick up what he can in a haphazard manner, and without anything that can properly be called instruction.

These views amount pretty much to the assertion that, wherever anything is to be learnt, the learner should have the guidance of a man experienced in that particular thing, and at the same time skilled in the art of teaching—an assertion that would not, I venture to say, be controverted by many in this country who have thought upon education or upon the teaching of trades. If the assertion be true, it seems to follow that, as all the manufacturing arts are merely applications of scientific knowledge, a full acquaintance with any one of them can only be had through the study of science on the one hand and through practical experience on the other; and, consequently, that an ideally perfect state of industry would imply a very considerable number of teachers giving instruction in all departments of scientific knowledge, and an equally large, or perhaps larger, number of men giving instruction in the practical details of the various trades and manufactures.

Referring for a moment to the circumstances of our own country, I may say, as regards the first of these two classes of teachers, that there exists at the present time a large accumulation of experience as to the most efficient methods of communicating scientific knowledge, and that I believe the attractiveness of the employment itself would, at any moment, co-operate with any active demand that might arise for such instruction in rapidly bringing into the field the requisite number of highly-skilled teachers. On the other hand, the teacher of what I may call practical workmanship would, I think, not long be wanting, should a real demand for his services arise; but great care would be needed to see that he were placed under circumstances in which it would be possible for him to work effectively. I have little doubt that some time would be necessary for the discovery of the arrangement that works best, consistently with the pecuniary means and other circumstances of his pupils, and consistently with the peculiarities of the trade he taught. In some cases, such as those in which there is no difficulty in bringing all the tools and machines of a trade within the compass of a comparatively small building, it would probably be found the best arrangement to carry on the teaching of the trade apart from an extensive work in which it is practised on the large scale; and it would, perhaps, be found in such cases, or in some such cases at least, convenient to carry on the scientific instruction fitted to that trade in other parts of the same building. But, on the other hand, the teacher of practical workmanship in trades that are intimately associated with the use of large and expensive machinery must necessarily hold his school within the gates of extensive works, as otherwise his pupils could not receive from him detailed instruction in the use and construction of all the machinery employed in their particular trade.

I may also remark, that there appears to me to be some needless mystification in our own country with respect to the meaning of the expressions "technical education" and "technical school." If I am correct in the views I have just expressed, technical education can be only one of two things, viz., either education or instruction in practical details, or education in the scientific principles and facts of which the trades and manufactures are the applications. I do not see that it matters much which of these departments of teaching is dignified with the name of "technical," for the question is merely one of conventional usage, but I may say that the expression "technical education" is commonly used in Germany to denote the scientific side of the education of a properly-educated artizan. If a distinction is really needed between the terms "technical" and "scientific," it might be well to use the former term in referring to science when taught with special reference to its applications, and the school in which such instruction is given would naturally be called a "technical school."

According to this definition of it, the technical school stands between the purely scientific school and what I may call for the moment the workshop school; and, if this relation were kept in view, the organization of a technical school, or what would perhaps be better, a set of technical schools, for a city whose educational, industrial, and economic conditions are all thoroughly known and specified, is not, I venture to say, a question of superhuman difficulty. From a knowledge of these conditions we could determine the trades that called for the establishment of technical schools; we could also determine the numbers, sizes, and situations of these schools that would be most generally convenient; and thence we could determine the teaching staff and the educational appliances of each. For the present the difficulty lies, I believe, not with the technical school, but with what I have called the workshop school; and I therefore look to the proprietors of our large industrial works for the solution of the chief difficulty that lies in the way of raising the skill of the higher artisans. The circumstances connected with the recent establishment in Cassel of a new Technical Middle School should, I think, convey a lesson to the proprietors of industrial works in this country.

This is one of the new Technical Middle Schools of Prussia, which I have already mentioned in connection with an interesting discussion that took place last year in the Prussian Chamber of Deputies on the whole question of technical education, and the importance of which discussion is shown, I may say, by the fact that it has been recently published at full length by the Prussian Government.

One of the important features of this new school is, that it is to consist of two departments—the lower embracing in its curriculum the subjects of a general education, calculated to prepare youths for the efficient study of the technical subjects to be taught in the higher department. The course of instruction in the preparatory or lower department is calculated to occupy a boy till about his 16th year, and a youth who has passed successfully through that department will be entitled to the privilege of serving only one year in the army. The course of study in the higher department, on the other hand, will last two years, and embrace technical subjects only. As yet, only one school of this type is in operation, and it is to be found in Cassel, for a reason that may be said to constitute the second leading feature of the school—viz., the combination of practical work in the workshop with theoretical instruction in the school. It so happens that, in Cassel, a Mr. Henschel possesses an extensive manufactory of railway plant, and is, at the same time, one of those who believe that the manual skill of workmen is not generally so much developed as it might be, if they were *taught* their trades in a systematic way by competent men whose sole business it is to teach. Mr. Henschel has agreed to receive into his works a number of young men, to whom he is to give, for two years, a systematic training in practical workmanship—a special part of his work's being set aside as a school, and suitably qualified men being chosen to give the instruction. So far as I know, these young men may come for practical instruction from any school, but there is no doubt that, in a short time, the instruction given in the new Technical Middle School in the town will be found to fit so well into the course of practical instruction in the workshop, that probably the greater part of the pupils of the latter will either have been pupils or will be about to be pupils in the technical department of the former. It is just because Mr. Henschel has been found so willing to co-operate with the Prussian Government in its efforts to bring about the efficient combination of systematic instruction in practical workmanship with school-instruction in technical subjects, that the new Technical Middle School has first been tried in Cassel.

The object of these new schools is to raise up, if possible, a numerous class of young men, qualified by high skill in practical workmanship, and by thorough knowledge of the scientific principles of their trades, to assume the posts of under-managers or foremen in the larger industries, and perhaps of proprietors in the smaller industries. It has been decided that these schools are to be established only in places where their pupils can have the advantage of receiving systematic instruction in the trade to which the scientific instruction given in the school refers; and, as a guarantee for the maintenance of the school in an efficient state, the Government requires that the local authorities, in places that desire to have such a school established, shall pay one-half of the expense of establishing it, as well as one-half of the annual expense of maintaining it. So far as I am aware, no definite resolution has been adopted as to the order in which the instruction in practical workmanship and that in scientific subjects shall follow each other, but the prevailing opinion among the best educational authorities in Prussia is, I believe, that the practical instruction should go before the theoretical. The reason assigned is that, after some practical experience, the meaning and value of the theoretical instruction is better understood. The wish of the Prussian Government seems, however, to be to leave open for the present the question of deciding upon the order in which the practical and the theoretical instruction are to follow each other, the object being to acquire experience on the point.

As a second example of a technical school for youths who leave the middle or secondary schools at about 16 years of age, I may take the so-called *Höhere Gewerbschule* in Chemnitz, which has been recently established by the Saxon Government, and is unquestionably one of the finest technical institutions in the whole of Germany. I have had the pleasure of going carefully through the whole building, and regret that, in the time at my disposal, it is impossible to do justice to the excellence of its arrangements and the completeness of its collections of apparatus and other appliances. I may say briefly that the building and fittings alone cost about £80,000.

Now, the pupils of this *Gewerbschule* are supposed to have attended one of the middle or secondary schools till about their sixteenth year, or, to speak more definitely, till they have acquired the right to the one-year's military service; and the course of instruction given in the institution therefore corresponds with that to be given in the technical department of the new technical middle schools of Prussia. There are, however, some important differences between the two schools, and perhaps the most important of these is that this Saxon school lays no stress upon the instruction of its pupils in practical workmanship. Another important difference lies, I think, in the fact that the course in the Chemnitz school is very long—viz., three and a-half years. However, as during that time instruction is given in several subjects that are not strictly technical, the comparison must not be pushed too far on that head.

Of the three courses of instruction given in this school to pupils who mean to follow the professions of technical chemist, mechanical engineer, and architect respectively, I may describe the first, as it will probably be most generally interesting. During the first year of his studies the attention of the young chemist is only partially given to chemistry, as it is thought advisable to secure, at an early stage, a sufficient acquaintance on his part with mathematics, mechanics, freehand, mechanical and architectural drawing, and physics. Accordingly, the programme of his studies for the first year is as follows:—

Inorganic Chemistry, . . .	4	hours per week.
Physics, ...	4	,,
Mathematics, ...	8	,,
Descriptive Geometry, . .	4	,,
Freehand Drawing, . . .	4	,,
Architectural Drawing, . .	3	,,
German Language and Literature,	3	,,

During the third half-year, in which the lectures on organic chemistry and practical work in the chemical laboratory are commenced, fourteen hours per week are devoted to chemistry, and instruction in descriptive geometry and freehand drawing is discontinued. From this point attention is given almost exclusively to chemistry during the remaining two years of the course, in the first of which it occupies twenty-one hours per week, and in the second twenty hours per week—the other subjects of study during these two years being chiefly mechanical drawing and the principles of mechanics and machinery.

As a third example of a technical school for youths who have been educated in a middle or secondary school up to their sixteenth year, I may take the so-called *Industrie-schule*, as it is to be found in the chief towns of Bavaria. In this school we meet with excellent arrangements for teaching at least the elements of practical workmanship to the students who take the course of instruction for mechanical engineers. In Munich, for instance, there is a workshop really well fitted up with tools and machines, many of which are driven by steam-power. During the two years' course of instruction the engineering pupils work in the shop five hours weekly. Besides the course for mechanical engineers, there is, as in the Chemnitz school, a course for technical chemists and a course for architects. All these courses extend over two years, and they are designed either to qualify youths to pass at once to the learning of their trades, or to pass into the Polytechnicum for a more extensive course of theoretical study. I understand that almost all the students leave the *Industrie-schulen* to enter the Polytechnicum in Munich, and therefore this form of school can scarcely be regarded as a proper example of a technical school that is to supply to youths of the middle classes a course of instruction suited to their opportunities and complete in itself. I may, however, give an example of one of the courses of instruction in the school; and, as I have mentioned a portion of the course for mechanical engineers, I may complete my statement of it.

FIRST YEAR.	Hours per Week.	SECOND YEAR.	Hours per Week.
Mathematics,	7	Mathematics (Higher),	3
Descriptive Geometry,	5	Physics,	4
Physics,	4	Applied Mechanics,	2
Machine Construction,	11	Theory of Machines,	5
Mechanical Drawing,	4	Machine Construction,	14
German, French, and English,	6	Mechanical Technology,	2
Practical Work,	5	German, French, and English,	6
		Practical Work,	5

The fragmentary account I have now presented of the technical middle schools of Germany will have been found, I think, to bear out my remark that the existing schools are not characterized by any uniform plan of organization. In point of fact, they generally seem to me to be in a state of probation and transition. The lines on which the new Prussian school, however, has been placed, seem to promise important practical results, and the friends of technical education in this country will not, I think, fail to watch its development with much interest.

I now come back for a moment to the schools that have been instituted for giving technical instruction to workmen, who, since leaving the elementary school at about fourteen years of age, have learned their trades in whole or in part, and are in a position to devote some time exclusively to the improvement of their education. These are the so-called *Baugewerkschulen*, and the instruction given in them consists, generally speaking, of such subjects as arithmetic, book-keeping, mathematics, freehand drawing, mechanical or architectural drawing, elementary chemistry, elementary physics, and the designing of machinery or of buildings. In most schools of this kind instruction is given only in winter, but in a few of those which are largely attended a summer course of instruction is likewise given. The entire course extends usually over three or four half-years.

All the German States give encouragement and support to these schools, and the total number of them is considerable. I am not in a position to state the average total attendance at these schools during the winter months, but it certainly amounts to several thousands. In the *Baugewerkschule* of Stuttgart, alone, the attendance is generally about 1200; and in the celebrated school at Holzminden in North Germany, and which, by the way, is the oldest school of the kind in Germany, the attendance is about 1000. There is also an institution in Hamburg of a nearly similar kind, attended during the winter half-year by about 1800 pupils. These are, however, the best attended *Baugewerkschulen* in Germany, and in very many of them the attendance does not average 100. The fees usually range from twenty to forty marks—(£1 to £2)—for a session of six months.

As regards the teaching of technical subjects in evening-classes, there is not very much to be said, since, with the exception of elementary mathematics and some branches of drawing, there is as yet little that can be called "technical" in their courses of instruction. Indeed, it is only in the kingdom of Würtemberg that regular teaching of these subjects is to be found on a considerable scale. However, it must be borne in mind, that the evening schools of Germany are very creditable institutions, and that their extension, both as regards number and educational scope, is evidently only a question of money and time. My experience of them is limited to Berlin, where they are all free. There the subjects at present taught are: grammar, composition, writing, arithmetic, book-keeping, elementary mathematics, and French.

From the hurried sketch I have now been able to put before you, it will be seen, I think, that while general education is in Germany at a very high pitch, technical education is not remarkably advanced, except in the case of the higher classes, who can afford to maintain their sons at school and college until the twenty-third or twenty-fourth year of their age. The important fact, however, has to be remembered, that Germany is really alive to the benefits of technical instruction for all grades of the people, and that she appears resolved to employ it at whatever cost, as a means of raising herself to a foremost place among the manufacturing nations of the world. As I have already said, her efforts in that direction should command our careful study; for, though we may be unable to make literal copies of her institutions, we cannot fail to obtain useful lessons from them. In particular, I would again commend to your attention the newly-instituted Technical Middle School of Prussia.

DISCUSSION.

Dr. MORRISON, Glasgow Academy, in reply to the call of the President, said he thought a single word from him would only mar the effect of the admirable paper which had just been read. Anything more clear, more pointed, more excellently expressed, he was of opinion could scarcely be brought before the Society. He had carefully studied some departments of German education, and had given a general attention to the whole educational system of that country, and in so doing had had occasion to read a considerable part of the literature on the subject, but he felt bound to say that he had met with nothing which, in so short a space, gave so full an idea of the whole system as the paper which had been read that night. There were many lessons to be learned from the Germans on the subject of education, and one of the most important of these, and one which he would like to impress upon parents, was that the sons of the poorest class in Germany remained at school beyond the age at which many of the sons of the wealthiest class in this country left it. He ridiculed the idea which prevailed in some quarters regarding the unwillingness of well-educated boys to pass through the initiatory drudgery of mercantile employment as a reason for withdrawing them early from school. He then referred to the uniform organization of the secondary schools of Germany, which prevented lads from entering the universities in an immature state of education, they being obliged to produce a certificate from the school in which they had been educated of their fitness for university studies. He could not sit down without expressing once more his exceeding satisfaction with the paper, and he hoped to be favoured by Mr. Dixon with an opportunity of becoming acquainted with the arrangements that he had made in the valuable institution over which he presided.

The Rev. Dr. DODDS, in response to the call of the President, said he concurred in the opinion expressed by Dr. Morrison regarding the value of the paper which had been read. Mr. Dixon had evidently thoroughly mastered the subject that he had brought before the Society. The paper was the clearest statement of the main features of German education that had come before him. He had had occasion to do his best to become acquainted with the subject of the paper, and had for that purpose referred to many sources of information, but he felt that he now knew a great deal more about it than when he entered the room. He thought it would be well that the paper should be published at once, without waiting for the completion of the annual volume of the Society's *Proceedings*, as it might be valuable in directing the movement at present existing in the city on the subject of technical education. He concurred in the opinion expressed in the paper regarding the probable failure of a Technical High School in Glasgow at the present time. He thought that schools should, in the first place, be established that would prepare the way for such an institution. He believed that was a very important point for the consideration of the trustees and managers of the various mortifications in the city, and he hoped that steps would be taken to bring the paper that had been read that night under their notice. Dr. Morrison had pointed out one of the great blots in the educational condition of Scotland. The more he saw of the state of education in elementary and other schools, the more he felt convinced that as a rule neither the parents of the pupils nor the managers of schools had accurate notions as to the true nature of education. So long as erroneous ideas existed on that point it would be vain to expect that boys would remain at school sufficiently long to take advantage of courses of instruction in scientific or other secondary subjects. He had been much struck with the statements in the paper as to the relations between the German universities and the secondary schools. He knew of nothing more prejudicial to the secondary schools of this countrv than the open gate whereby the universities admitted without examination boys who, for years to come, should have been pupils of these schools. The universities competed for pupils with the secondary schools, and until the universities took their proper position, and insisted on an entrance examination, the secondary schools must necessarily languish. He also regretted the practical inability of school boards, in the present state of public opinion with regard to education, to carry into effect the compulsory clause of the Education Act, and stated that large numbers of children were allowed to leave school little over eleven years of age, with only the merest rudiments of education, and without having received enough to produce a desire for more. He entirely exonerated the teachers of the schools, and attributed the low state into which Scottish education had fallen to a declension in the popular appreciation of it. He sat down after expressing the very great pleasure he had had in listening to the paper, and remarked that they were exceedingly fortunate in having had such a paper read so opportunely before them that night.

Dr. GEORGE BUCHANAN, Professor of Clinical Surgery in the University of Glasgow, asked a question as to the status and emoluments of the professors in the German universities, which was answered by Mr. DIXON to the effect that the ordinary professors were State officers, and derived their incomes chiefly from the State.

Mr. JOHN D. CAMPBELL drew attention to the possible danger of over-education in the way of theory.

On the motion of Mr. JOHN MAYER, seconded by Mr. W. R. W. SMITH, the discussion was adjourned till 14th January, 1880.

Mr. W. R. W. SMITH, who opened the discussion, said—Having educated a family of sons, I must speak from the point of view of my own experience. My effort was to impart a sound elementary Scotch education, with a knowledge, from residence on the Continent, of French and German, and the result had realized my expectations. My business relations on the Continent had given me an insight into the working of the technical education, so far as it had gone, and I had come to the conclusion that any attempt to teach trades in school was a grave mistake, and the position of the German mind on this question, as mentioned by Mr. Dixon at page 87, entirely supports my view of the case.

There are, so to speak, two educations in a man's life. The boy is educated up to fourteen years of age, largely by rote and memory; but after that age a great physical, and also a great mental change takes place. From fourteen to sixteen years of age a lad can be educated intellectually in a manner which is not possible before that age. But suppose we took a young man of sixteen years, and continued his education in a technical school, teaching him a trade, it would be found that he was of no use in that trade when he was eighteen or twenty years of age; and the reason is plain—when sixteen was the very time when knowledge of the right practical life-kind, with actual work, could be imparted and correct habits formed—whereas these attempts at teaching a trade only stereotyped certain ideas on the young lad's mind; and therefore Mr. Dixon's illustration on page 90 of his paper, with regard to Mr. Henschel, interested the speaker exceedingly. Now, supposing all the world were of Mr. Henschel's mind, they would get on very well with technical education; but all the world were not. There were many young men who ought to be encouraged to go on with their education in technical subjects; but suppose they took a capable teacher and put him into a technical school, they arrested his practical progress at that point, and the teaching from him was merely the teaching from the experience he had gained up to that period in mechanics or any other trade. But suppose that teacher had been continued in the work from which he had been taken, such as manager of it, he might have been advancing in usefulness to his employer and the world. For instance, the master comes to him and tells him that some of their product does not suit the market for which it is intended, and that a customer asks a change—perhaps a difficult one to arrive at—and which can only be arrived at after much hard thought, master and foreman consult, and, after considerable trouble, by a different method of manipulation or process, he produces the article required for the special market. Here, then, we have the teacher at a special disadvantage, and the pupils getting the old knowledge of production that the markets of the world are refusing. Such cases are known to all engaged in many of our manufacturing processes, and one notable case comes to my memory. A certain style of goods, some years ago, were made by one house in Glasgow, with special excellence, and their competitors could not come up to that point of excellence. By accident I was shown into this room by the manufacturer, who was showing his works to a friend of mine, and as the process of perfection in the goods was exceedingly simple, the manufacturer suddenly turned to me and said I must go out. I said it was too late; I had seen it all. I promised to be in honour bound not to disclose what I had seen, and it was one to two years after ere the process was discovered by any one. He asked whether a technical teacher would be admitted into such works, and whether he could teach such processes, with the improvements coming from time to time. He therefore contended that the appointment of technical teachers arrested their progress, and consequently could not make a tradesman of a boy-pupil. He believed if they could get a sound elementary education into our young men, with, to a certain extent, models and processes shown to them, with the proviso distinctly and repeatedly told them—"You are not learning from me your trade; you have got to go to learn your trade in the shop, and to work long and steadily before you learn it," that then they would make an improvement upon the German method. He held that one of the great failings in our country at the present time was the abolition of the old system of apprenticeships in trades. If they were to progress in technical education as they desired, if they were to progress well as in olden times with good workmen and good foremen, they must have the old system of apprenticeships enforced by law, and carried out in something like the following fashion:—A youth apprenticed must work for so many hours a day, and so many hours study, and as the apprenticeship came to a conclusion, he must choose to take either so many more hours work, or so many more hours of study per day. Without some process of that kind any attempt to introduce technical education in teaching trades in school would be found to be a gigantic error, as it had been found to be in Germany. He recommended all the members present to pay a visit to Mr. Dixon at Allan Glen's Institution, where they would see the progress that had there been made in the subject, and the utmost extent to which technical education should be carried; but of this I am convinced, that a long school education after sixteen years of age, unless for some special profession, makes a wholly, or nearly wholly, useless man in ordinary commercial life, and even in any special profession the special education and the daily work must go on together, if we are to have thoroughly practical useful men.

Mr. Gustav Jacoby said that the system of apprenticeships which Mr. Smith recommended was, to his (the speaker's) sincere regret, the one that was actually existing in Germany in almost every trade, and which was proving a very great obstacle to all their progress. If Mr. Smith had made his proposition in Germany, he would there have been considered a reactionary gentleman, because it had cost them in that country a fight of many years in trying to uproot that system, which, unfortunately, was still existing in most of their trades. Even in mercantile offices it was still the fashion in Germany that a boy from school must engage for three or four years to serve without any remuneration and without the slightest encouragement. He (the speaker) went to a technical school in Germany (if, in accordance with the German custom, he might comprise the Commercial or *Handels-schule* among technical schools) at eleven years of age, and he had completed the whole course at fourteen; and when he offered himself as a candidate for a situation in a large merchant's in Leipzig, and the merchant proposed to him the usual agreement, he said he would sign no agreement, because he thought he was quite capable to undertake a clerkship. He was taken on, and after three months he obtained his salary, while a good many other boys who had not been at a commercial school were going through their four years and had never received a penny. Now his own case was only an instance showing the way in which in Germany those who had received a special training generally obtained preferences, in all trades, over those who served as common apprentices. He, while expressing his admiration for the able manner and accuracy with which Mr. Dixon had represented the general school-system of Germany, and the opinions there prevailing regarding technical education, ventured to make a slight objection to the statement, "that the expression 'technical education' is commonly used in Germany to denote the scientific side of the education of a properly educated *artisan*" only. He thought it was used in a much wider sense, and that schools of commerce and of agriculture were commonly comprised under the technical schools. But, at any rate, the speaker could not help calling special attention to the "*Handels-schule*," being deeply convinced of the great importance and even urgency of having such an institute created in Glasgow. The proposition which Mr. Dixon had described as being considered in Germany an axiom: "that the time required by any given youth to learn his trade depends very much upon whether he receives systematic teaching in its processes, ... or whether he is allowed to pick up what he can in a hap-hazard manner, and without anything that can properly be called instruction"—this proposition applied most forcibly to the mercantile profession. In his own business he had perhaps had a dozen boys as apprentices from Glasgow academies. They came to his office; their parents were well off, and he often wondered how these parents could send those boys half-educated to enter upon a mercantile career. Those boys, in some cases, remained in the office five or six years, and they never acquired the knowledge that they would have acquired in two years at a commercial school—there was no time in the office to teach them. Their total ignorance of foreign coins, weights, and measures, or exchange usages, impaired their usefulness for ordinary calculations. Customers abroad mostly objected now to buy in English values. They telegraphed offers, all charges, and even foreign duties, included in the price. So difficult were such calculations for Scotch boys that they invariably got confused with them. The consequence was, that in almost every shipping office a number of foreign clerks, who have been trained in commercial schools, occupied the most remunerative places. Was that a satisfactory state of things? Why could we not have in Glasgow a school for training boys for a commercial career, as they had in Leipzig, Dresden, Magdeburg, Frankfort, Hamburg, or Antwerp, and other places? Why should we not have the same system which had enabled him as a boy of fourteen to speak French and English, and to be able to translate any English or French letter? He had had clerks in his office for ten or twelve years, and with all the drudgery of studying foreign languages they were not able to master them. Why? Because they began to study at night, when they were wearied and worn out—when the mind had no longer any strength to enter on such studies. He himself had tried after school to master Spanish and Italian, but he had never been able to make sufficient progress to write in these languages. He could think in English and in French quite as well as in his native German, because he had learned these languages as a boy. He desired no technical education without a thorough general education as a foundation.

Professor Dickson, referring to the action of Mr. Henschel, in Cassel, the owner of an extensive manufactory of railway plant, who receives into his works a number of young men and gives them a systematic training in practical workmanship, said that he could conceive of this being done by public-spirited men, but it seemed to him that he gave a certain proportion of his time and that of his employés to the instruction of his pupils, and was thereby taking away a certain amount of productive labour which he could employ to better purpose otherwise. This was extremely benevolent, but he would like to know how far it would fall in with his own interest, and what likelihood there was of a similar scheme being adopted by great employers of labour, whose works were in proximity to the technical schools proposed to be established.

Dean of Guild MIRRLEES, at the call of the President, said he did not see how the system of Mr. Henschel could work profitably. It might be done on the principle of philanthropic self-denial, but he did not see how it could be worked profitably in this country.

Mr. DAVID ROWAN said he had listened attentively to the remarks which had been made by Mr. Smith and the gentleman who followed him. They had each used the expression technical education very frequently. It appeared to him, however, that the meaning of the expression required definition. Even in Mr. Dixon's paper, which he was sure had been perused with much interest, at page 89 we have the following:—"Technical education can be only one of two things—namely, either education or instruction in practical details, or education in the scientific principles and facts of which the trades and manufactures are the application." It appeared to him that the modern acceptation of the meaning of the expression "technical education" was neither the teaching of science or trades by apprenticeship, but the mode or method of using the results of scientific teaching to the solution of the numberless questions which are ever presenting themselves in the workshops. Thus arithmetic, or the science of numbers, may be taught as pure science, just as algebra, geometry, or trigonometry may be taught, yet every book on arithmetic presented numberless questions relating to trade and commerce, which may be called the technology of arithmetic. When his friend, Mr. Jamieson, and he attended classes nearly forty years ago, lectures were given on the subjects of natural philosophy and chemistry, with courses on mathematics, drawing, &c. It is true there was a day-class, attended by a very small number of students, on practical chemistry, but the application of the teaching of the natural philosophy class to any question connected with the workshop was not dreamt of, and precisely the same with mathematics. In those days there were few periodicals on mechanical questions.

A very excellent technical college had within recent years been established in Japan. There had not previously existed any manufacturing industries in the country, and it was found necessary to establish trade schools for the making of models and small machinery, so as to admit of the technical application of the knowledge thus acquired to trades and manufactures. When technical schools were instituted in Germany there were but few trades or professions there; and at the technical school it was found necessary to adopt a similar method to that now existing in Japan. At these schools science was not taught, but merely the application of it to trades and industries. The student who was admitted to the technical school could only do so after having passed a very rigid examination, and which could only be reached at the age of nineteen or twenty years. He was supposed to have acquired previously all the scientific knowledge necessary, and was thereafter only taught its application.

In our country—essentially one of manufacturing industries—trade schools were not required. What we most need is secondary and science schools for youths after leaving the elementary schools—say at twelve years, until they reach the age of fifteen or sixteen years; and, after that, when the pupil becomes an apprentice, he could attend evening-classes—say for three sessions. He would thus have every opportunity during the day of applying in practice what he was taught in the evening. The fees at these schools should be as low as possible. By far the larger portion of our population are workers, and opportunity should be given to the sons of working men. In our country we need not hope to see all the people highly educated any more than we may expect to see them all wealthy.

Dr. Mills (whose address was read by the Secretary) said he had seldom perused a more able or lucid paper upon any topic than Mr. Dixon had presented to the Society upon the subject of technical education. As Professor of Technical Chemistry in Anderson's College, Glasgow, the question had often occurred to himself—How can we benefit technical education in Glasgow? In the first place, he considered the condition of even the existing "better class" schools extremely unsatisfactory. The greater part of them laid much stress on subjects which admit of display, such as music, elocution, language in its conversational form, &c., while the solid practical requirements of a great industrial city were not developed, or kept in the background. In most of them the holidays last three months at least—a length of time most unjust both to teacher and child. Another, and very grave evil, was the early age at which children in Glasgow are removed from school. The last years of school life so much exceeded in value all the others, that no parent could be justified, unless by the severest want of means, in stopping short the education of his family under the age of sixteen.

A boy intended for technical pursuits should have the working side of instruction always turned towards him. He should be urged to train both hand and eye by practice with the lathe, the carpenter's tools, the blowpipe, and the pencil; his mathematics should be illustrated on thread or surface figures of his own design; his linguistic lessons should be with a view to accurate speaking, writing, and translating—not for literary or rhetorical effect. He should be taught geography, with reference to climate, race, intercommunication, and the nature of produce; chemistry, physics, and geology, with reference to nature as a working power—not as a book. Nor ought he to leave school without knowing some of the rules, and the reasons for the rules, of success in life—those elements of morals, of political and financial interdependence among men, which we designate under the collective name "Social Science." All of this was successfully done in cheap London schools. Why not in Glasgow?

One direct consequence of leaving school at so early an age was the evening-class system—a system which, the speaker affirmed, educating a very few at the expense of the many, and more especially at the expense of a well-trained lecturer, was a lavish waste of teaching power. It was the universal experience that very little real result was actually, or ever was likely to be, attained by teaching young lads already tired with a day's work, or young men past the age when intellectual digestion is easily accomplished. Evening-classes, he believed, would cease to exist as soon as parents kept their children at school until the age of at least sixteen years, and there taught them, at their most receptive age, the scientific elements of a practical education.

Upon the subject of the duration of special instruction much misconception prevailed in Glasgow. While it was invariably allowed that the acquisition of an ordinary trade takes three years at least, nothing was more common than to suppose that six months' analytical training would suffice to fit a young man for the chemical managership of a work.

Then, again, the disunion among technical institutions was very deplorable. Anderson's College, the Mechanics' Institution, and the Technical College (actually existing in a weaving branch), and the Athenæum, were all virtually engaged in the same pursuit; and it had been actually proposed to start, in addition, a technical school in connection with Kelvingrove Museum. This meant a further waste of teaching power, waste of money on rent, and waste by duplication of educational appliances.

Summing up, Dr. Mills considered the following reforms to be imperatively required for the advancement of technical education in Glasgow, viz.:—

(1) Practical education at school until at least sixteen years of age.

(2) Subsequent study at a technical college for at least three years.

(3) The actual formation of a united central college by the incorporation and further endowment of existing technical institutions.

He who should effect, or labour to effect these reforms, would deserve the lasting gratitude of a great community.

Mr. C. C. LINDSAY, C.E., said—I have read Mr. Dixon's paper with great interest. He has succeeded in giving a very comprehensive idea of the present position of scientific and technical education in Germany within a very small compass. This country has a great deal to learn from Germany with respect to its systematic teaching—its primary, practical, and polytechnic schools forming a systematic whole. As honorary secretary of the Glasgow Mechanics' Institution, I have been led to give the subject of technical education some study during the past few years, and perhaps a few remarks upon the proposed adoption in this country—by Mr. Dixon—of the system which obtains in the technical middle schools of Prussia, may not be without interest. I am afraid such a system would be detrimental to our interests, and its adoption would tend to reverse our present position as an eminently practical people. On the other hand, the system in Germany has made its people too theoretical, while our system, or rather want of system, has driven us to the other extreme. Surely there is a middle course with respect to theoretical education which it would be judicious to aim at. Being best acquainted with engineering, I will confine my remarks more particularly to its requirements, though it seems to me that the arguments are equally applicable to the manufactures.

It is stated in a publication, issued in 1870 by the Institution of Civil Engineers, on "The Education and Status of Civil Engineers in the United Kingdom and in Foreign Countries," that it is essential to distinguish clearly between the two kinds of education which it is generally deemed desirable an engineer should receive.

"In the first place, he should be acquainted with such physical sciences as bear on his profession, and should be familiar with the rules and operations necessary to apply their principles in practice. The imparting of this knowledge may be termed the theoretical education of the engineer. Secondly, he must be acquainted by actual experience with the nature of practical works, and with the operations and processes necessary for their design and construction. The obtaining of this knowledge is his practical education." How is this theoretical and practical knowledge to be obtained? and would it be advisable to introduce the system adopted in the technical middle schools into this country for that purpose? The introduction of such a system would, I fear, be followed by a falsely high estimate of the value of the practical instruction, and, in the case of civil engineering students, this royal road to practical knowledge would be substituted, in the majority of cases, for the strictly business-like proficiency in practical work which is to be gained in our engineering establishments.

I am convinced that it cannot be obtained in the workshop of a school, with its five hours' practice a week, and that nothing but regular attendance and constant application to work for a prolonged period can ensure dexterity of eye and hand, and a knowledge of practical details. In the publication referred to, with but two exceptions, the advisers of the council of the Institution advocated our present practical method of instruction, and the institution of a system of education in the applied sciences. I think we can take a very good lesson from the action of the City Guilds of London with reference to technical education, acting on the advice of Sir Wm. Armstrong, and Mr. G. T. C. Bartley, Lieut.-Col. Donnelly, Capt. Douglas Galton, Prof. Huxley, and Mr. H. T. Wood. They, doubtless you are aware, have instituted and endowed the City and Guilds of London Institute for the advancement of technical education. Each of the gentlemen named advocated the teaching of the practical part of the trade or manufacture, apart from the Institution, which is devoted to theoretical instruction, and considered that the practical part should be left to be acquired in workshops and manufactories by means of apprenticeship or otherwise.

I consider that the best means for facilitating the acquirement of technical knowledge—or science applied to practice, and illustrated by models, apparatus, and diagrams amongst the industrial classes—would be the institution of a few technical training colleges, for lecturers and teachers, at industrial centres, for I think you will agree with me that it is very difficult to find men capable, or with the art of imparting technical instruction; and also the institution of systematic courses of instruction, extending over several years, similar to those adopted in the Watt Institution, Edinburgh, Allan Glen's Institution, and the Glasgow Mechanics' Institution, but more closely allied to the board schools, so that such institutions might take up the education of boys where the board schools leave off. That is the system I would propose as best adapted to this country; and if engineers and manufacturers insisted that their apprentices should attend schools where this systematic technical instruction is given, I am confident that this country would soon hold a high position with respect to technical education, and continue to hold her present position as the foremost nation in the arts and manufactures.

Mr. **John L. K. Jamieson** said his impression was that, so far as the mechanical industries with which he had been connected were concerned, their requirements were being met at Anderson's College. They had there at present about 250 youths of the bone and sinew of the city, who came several evenings in the week, and were taught how to apply science to the mechanical arts. He did not believe that young men who commenced work at six o'clock in the morning were unable to spend two or three hours at night in acquiring scientific knowledge. He thought it would be advisable for persons connected with each of the various trades and manufactures of this district, to appoint committees for the purpose of studying the whole question of education, and of advising how a better system of instruction than at present existed could be given.

Dr. **J. R. Wolfe** said that the subject of Mr. Dixon's paper was of serious import to this vast empire. Hitherto this country had been favoured by fortune in being able to keep its ground in the markets of the world. Our insular position has kept our workshops from being distracted by foreign wars. Now, the question was—How long should we continue to hold our own? It is evident that, if we are to hold our own in the world, we must advance our educational system, and not fall short of that model described by Mr. Dixon. It is remarkable how the ancient classics, which were formerly considered the highest type of education, are now giving way to the study of modern languages, and that the "*Realschulen*" have gradually gained in importance. This is by no means to be regretted—it is in conformity with the spirit of the age. In this country, Mr. Robert Lowe, himself a great classical professor, spoke last year rather more in favour of the cultivation of modern languages. Hence, the great importance of the cultivation of music and painting as an essential element in the culture of a nation. These branches should not be studied as a profession, but should be taught to children of both sexes along with their "Step by Step." This cultivation would accompany them and put its impress upon all their doings, and all their productions would be marked by the same love and appreciation of the beautiful. It was to be hoped, at any rate as far as Glasgow was concerned, that this discussion would lead to some practical results. The second city was most favourably situated for the initiation of a technical school, which might not only be made a model to the whole country, but might rival the German system under consideration. They in this city possessed a plant such as no other city can boast of. They had the power, if they only appreciated the interests at stake and put forth an effort to collect the means scattered among the tiny foundations or mortifications, to establish a technical college which would reflect renown upon this city, and be the means of initiating throughout the country a system of technical education which will maintain the prosperity of the empire.

Mr. DAVID SANDEMAN said—The great obstacle in the way of carrying out a course of thorough technical education, such as that advocated in Mr. Dixon's admirable paper, is the unwillingness of parents to allow their children to remain at school the necessary length of time. It is possible that their ideas may undergo a change in this respect, but until then, I think that we should do our best with the means and material at our command.

The Anderson's College, the Mechanics' Institution, Allan Glen's Institution, and the School of Design, when properly endowed or supplemented, would be in a position to undertake the scientific instruction of the youth of Glasgow for many years to come, the practical application of which could be acquired in the school or workshop, as might be considered most suitable, by those engaged in the various branches of industry.

The Weaving School in Well Street appears to be supplying a a want which had been felt, the number of students in the

First Session having been - - -	40
Second do., - - -	49
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and I may mention, as a gratifying fact and as a proof that trades' unions are not unfriendly to technical education, that two tenters are among this year's students. I may further state, that the success attending this school has led its Trustees to consider the desirability of adding to it a dye-house as soon as adequate funds shall be forthcoming.

Mr. **Thomas Muir**, Vice-President, said that, rather than give any opinions of his own, as the President had suggested, he would prefer to draw attention to one or two unsettled points in the hope of eliciting still more information from the gentlemen of practical experience who were present. In the first place, it seemed to him that there had been made manifest a considerable diversity of opinion not only as to when technical education was to be begun in a pupil's course and where it was to be carried on, but also as to what it really was. In these circumstances it would be a very valuable contribution to the discussion if Mr. Dixon would sketch in its full extent such a curriculum as he would approve of for a pupil who was intended by his parents for a technical pursuit.

Again, reference had been made by more than one speaker to the harmful practice of withdrawing boys from school at too early an age, and it had been well said that in the great majority of cases a year at school, after the age of thirteen, was worth more than any two before it. But how often, on the other hand, did one hear it asserted that soundly-educated lads of seventeen or eighteen were not wanted in business—that the boy of thirteen or fourteen was more serviceable at first, and greatly superior afterwards? Now, where lay the truth in this matter? The question, it must be borne in mind, was not which of the two at eighteen was the more useful to his employer, but which was the more useful at twenty, the more enterprising and prosperous at twenty-five or thirty, and the more valuable citizen generally for the remainder of his life.

Mr. **Wm. Caldwell** gave it as his experience of more trades than one for many years, that the demand for higher skill on the part of the workman was by no means so great as many advocates of technical education appeared to suppose. He said it was by no means uncommon to find an inferior workman with comparatively little knowledge of his trade preferred to a more experienced man. This occurred principally in shops where articles of an inferior quality were made to meet the popular demand for cheapness. He believed that nothing would contribute so much to the raising of the skill of our artisans as an increased demand on the part of the public for good substantial work.

Mr. David Thomson, I.A., said that the increasing demand of the public for cheapness tended powerfully to repress the skill of our artisans, as it led to the manufacture of inferior articles by other than highly skilled and conscientious workmen. The keen competition between the masters in the matter of price prevented them from combining to put an end to the many malpractices which now prevail in all classes of manufactures, and the only hope of remedy appeared to him to be in getting the trades' unions to take up the subject and make it imperative that all apprentices be thoroughly trained to their craft, and that they be duly proved before receiving certificates of craftsmanship; and, further, that they, the craftsmen, should take combined action, and refuse to execute work of a shoddy, artificial, and fraudulent character. Some reformation of this sort would, he thought, have to be made before technical schools could be properly developed, and do the good they are so well calculated to perform.

Mr. Dixon said in reply that, with the exception of a remark by Mr. Jacoby upon the meaning of the term "technical school," there had been throughout the discussion no direct criticism of his paper. Whether the *Handels-schule* of Germany were or were not usually included under the term "technical," he concurred in the opinion of Mr. Jacoby regarding its value, and the desirability of having similar schools in at least the large commercial centres of this country.

The discussion had been at anyrate suggested by his paper, which had therefore supplied a certain amount of recent and, as he believed, reliable information concerning the technical schools of Germany, and had also called forth the opinions of many who were interested in the instituting of similar schools in this country. He had been much gratified to witness the great amount of interest now taken in technical education, although he must admit that, as yet, opinion on the subject is somewhat chaotic. He had noticed, however, that a few fundamental points had received clear recognition from several speakers. He referred to such points as the necessity for scientific instruction as a basis for all thorough technical training, to the superiority of instruction in day-classes over instruction in evening-classes, and to the necessity of school attendance till about the sixteenth year of the pupil's age. However opinions might differ regarding the best or most convenient ways of carrying out these principles in practice, it seemed to him that little divergence of opinion existed regarding the principles themselves. The whole discussion had, indeed, struck him as being decidedly in advance of previous discussions on the same subject to which he had listened, and he fancied that it had shown in particular a decreasing liability to dread the "theoretical" as the negative of the "practical."

Mr. Muir had proposed to him the task of sketching out a full curriculum of study for a boy intended for a technical pursuit. This was more than he could undertake to do, as the curriculum must be adapted to the trade or profession the boy is intended to follow, and to the amount of time that he can devote to the learning of it. It was for these reasons that in Germany the organization of the technical high schools, the organization of the technical middle schools, and the organization of the Baugewerkschulen are all different from each other; and a corresponding difference would show itself in this country when the organization of our technical schools came to be taken up in earnest. Mr. Smith had advised all who were interested in the organization of technical schools to visit Allan Glen's Institution, and he (Mr. Dixon) would be happy to show them everything connected with it, as perhaps the best means he had of meeting Mr. Muir's request. He might say that they would there find a school organized to carry on the education of a boy from his sixth to about his sixteenth year, and to supply him, particularly during the last four years of his course, with instruction in those branches of pure and applied science that chiefly underlie the industrial arts. They would find that great importance is attached to the study of English, and, after that, to drawing, modern languages, mathematics, physics, and chemistry. They would find that as pupils advanced towards the highest class in the school, their attention was more and more directed to mathematics, freehand and mechanical drawing, machine construction, theoretical and applied mechanics, and chemistry. They would find generally a liberal supply of scientific apparatus, and, in particular, they would find a well-equipped laboratory, in which pupils were, in the first place, trained to repeat the chemical experiments they witnessed upon the lecture-table, and were afterwards taught a systematic course of chemical analysis. They would also find provision made, in the shape of a workshop, for teaching the advanced pupils the use of the ordinary tools for the working of wood and metal, and for showing them the practical application of much of the theoretical instruction given them under the heads of Theoretical and Applied Mechanics, and of Machine Construction. They would find all this done with the object of enabling boys to proceed to the learning of their trade elsewhere with intelligence and ease. They would certainly not find any belief in the possibility of teaching any trade in the school.

Referring to this latter point, he hoped that from the paper that he had read no one would gather that any considerable educational authority in Germany was at present advocating the teaching of trades in connection with schools. It was expressly stated in the paper that it appeared to him to be as good as universally accepted in Germany "that a youth can only learn his trade properly when he is surrounded by all the tools and appliances actually used in his trade, and with all its processes continually under his view." There was, however, something more to be done than to protest against the attempt to teach lads their trade in school. They had to recognize the fact that in this country there is almost no such thing as *teaching* a trade anywhere. He could have liked to hear in the course of the discussion a protest against the *neglect of teaching trades in the right place,* no less emphatic than the protest they had heard against the *attempt to teach trades in a wrong place.*

VI.—*On a Substitute for Euclid's Third Postulate.*

By Mr. R. F. Muirhead, B.Sc.

[Read before the Society, January 7th, 1880.]

Every logical system of geometry must presuppose as its foundation a certain number of principles expressed in the form of geometrical theorems. In Euclid's "Elements" the theorems that are assumed without proof are mostly of a very self-evident character, and they are called by Euclid Axioms. But the "Elements" not only form a system of geometry, but also give the solutions of a number of problems. In order to accomplish the latter result it is necessary to assume the solutions of certain simple problems as a basis. Euclid assumes three such solutions, and calls them postulates.

It is an interesting question to consider how systems of geometry could be constructed that would start from postulates different from those of Euclid. Such considerations would tend to give clearer views of the system of Euclid itself, by enabling us to compare it with others.

The following investigation is an attempt to construct a system of plane geometry similar to that of Euclid, but with a new postulate substituted for the third in Euclid's list. The proposed substitute is this :—

From a given straight line, at a given point, a part of the line may be cut off equal in length to a given straight line.

It may be noticed that, whereas the operation corresponding to Euclid's postulate — namely, drawing a circle—is one of the functions of a pair of compasses, the other function—*i.e.*, transferring a length from one length to another—corresponds to my new postulate.

Further, Euclid's postulates include the construction of one nonrectilinear curve—the circle—mine only include that of the straight line. On this account they are less fruitful than those of Euclid, as will be seen in the sequel. It would have been quite as easy to assume as postulate the construction of a more complex curve, such as the parabola, which would have rendered possible the solution of problems such as the duplication of the cube, which are insoluble by Euclid's method.

I have confined myself in this investigation to Euclid's geometrical methods, with one exception. I have in one or two cases overtly made use of hypothetical constructions. I say overtly, for I cannot consider Euclid's method of superposition to be anything but an hypothetical construction; for the superposition is to be done mentally, not carried out practically.

It is scarcely necessary to remark that proofs are quite as rigorous with hypothetical as with practical constructions, if only the possibility of the construction be shown. To make this obvious, it is only necessary to point out that Euclid's proofs depend for their validity, not on the accuracy of the construction, but on the fact that Euclid's constructions always contain implicitly a proof of their own possibility. However, following Euclid, I shall use hypothetical constructions only where it is absolutely necessary.

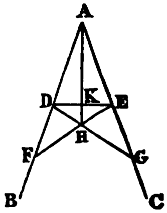
I shall now proceed to demonstrate most of the propositions in the first book of Euclid.

Euclid I. 2.—This proposition follows immediately from Euclid's first postulate and the proposed third postulate.

I. 3.—The assumption of the solution of this problem forms the new third postulate.

I. 4 to I. 8 are proved exactly as in Euclid.

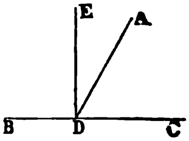
I. 9.—In order to solve this problem, let the following construction be made:—From A B and A C cut off A D and A E equal to one another, and also A F and A G equal to one another. Join D E, F E and D G. Let D G and F E meet in the point H. Join A H. A H will bisect the given angle. Let A H meet D E in K.



It is evident that A D E is an isosceles triangle, and that it may be proved, just as in Euclid's demonstration of I. 3, that the angles A D E and A E D are equal to one another, and also that the angle H D E is equal to the angle H E D. From the latter equation by I. 6, it follows that H D is equal to H E. Since the angles A D E, E D H are respectively equal to the angles A E D, D E H; hence the whole angle A D H is equal to the whole angle A E H.

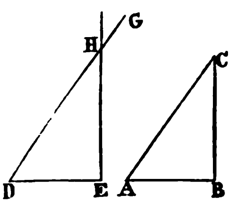
We have now in the two triangles, A D H and A E H, the two sides A D, D H equal respectively to the two sides A E, E H, and also the contained angles A D H, A E H equal to one another. Hence, by I. 4, the triangle A D H, A E H are equal in all respects, and, consequently, the angle D A H is equal to the angle E A H. That is, the given angle B A C is bisected by the straight line A H.

I. 13.—The proof of this proposition is the same as Euclid's, with the exception that the construction is hypothetical. The justification of this construction is obvious, for by the definition of a perpendicular, it must be possible for a straight line to be drawn at right angles to a given straight line from any point in it.

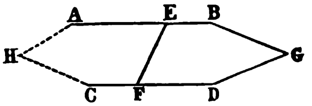


I. 14 and I. 15 are proved as in Euclid.

I. 26.—First part with a generalization. Let there be given a triangle, and a figure having the same base and the same angle at the base, then shall the sides of this figure, when produced, meet and form a triangle equal in all respects to the given triangle. This is proved by the method of superposition. Let the base D E be superimposed on A B, so that D coincides with A, and E with B. Then shall the sides D G and E F fall on A C and B C respectively, since the angles at D and E are equal to those at A and B respectively. Hence, D G and E F must, like A C and B C, meet, and the point of intersection H must fall on the vertex C of the triangle. Hence, it is obvious that the triangle H D E coincides with the triangle A B C, and is equal to it in all respects.

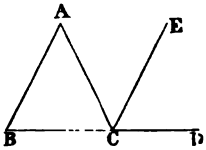


I. 27.—This proposition is proved by means of the preceding. We at first proceed as Euclid does. If A B be not parallel to C D, the two lines must meet. Let them meet in G. G E F is a triangle. Now, since by hypothesis the angle A E F is equal to the angle E F D, we can easily prove by superposition that the other alternate angles B E F and E F C are equal to one another. For if D F be made to fall on A E, so that F may coincide with E, then the whole line D F C will coincide with the whole line A E B, and also the line F E with the line E F, since A E F is equal to F E D, and hence the angle E F C, coinciding with the angle B E F, must be equal to it. We have now a triangle G E F, and a figure with an equal base E F, and equal angles at the base—namely, A E F equal to E F D, and C F E equal to B E F. Hence, by the preceding proposition, A C E F is a triangle equal in all respects to G E F. Therefore A B and C D meet also towards A and C in a point H. Hence, the two straight lines H A B G and H C D G enclose a space, which is impossible. It must be impossible, therefore, that A B and C D can meet. Hence they are parallel.



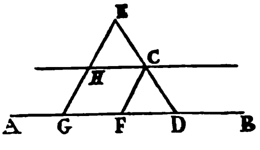
I. 28, I. 29, and I. 30 are proved exactly as in Euclid.

I. 32.—This proposition is also proved as in Euclid, but the construction is hypothetical. In order to justify it, the following considerations are sufficient:—If a line C E be drawn parallel to B A, it cannot fall on C A, for C A meets B A. For a similar reason it cannot fall on B D nor between C A and C B, for then it would meet A B.

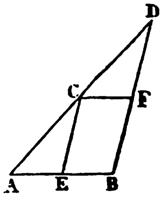


Hence it must fall between C A and C D. The rest of the proof is the same as Euclid's.

I. 16 follows as a corollary from this; and I. 33, I. 34, and I. 17 are proved as in Euclid.



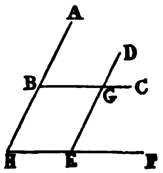
I. 31.—Let A B be the given straight line, and C the given point. Through C draw any straight line C D meeting A B. Produce D C to E, and make C E equal to C D. From D A cut off D F and F G, each equal to C D or C E. Join C F, E G, and cut off G H equal to F C. Join C H. C H shall be parallel to A B. By I. 32 the sum of the interior angles of the triangle D F C is equal to that of the triangle D G C. From these take the common angle D. Hence the sum of D C F and D F C is equal to the sum of D E G and D G E. By construction, D C is equal to D F. Hence the angles D C F and D F C are equal to one another, and each is equal to half their sum. Similarly each of the angles D F G and D G F is equal to half their sum, and hence equal to D F C or D C F. Since C F D is equal to H G F; hence, by I. 28, C F is parallel to H G. Consequently, by I. 32, H F is a parallelogram, and C H is parallel to A B.



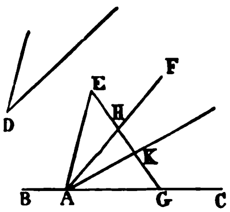
I. 10.—Let A B be the given straight line. From A draw a straight line A D, making any angle with A B. From A D cut off A C equal to A B, and C D equal to A B or A C. Join B D. Through C draw C E parallel to D B, and C F parallel to A B. A B is bisected at E. For by I. 29 the angles E A C and E C A in the triangle E A C are respectively equal to the angles F C D and F D C in the triangle F C D, and the base A C is equal to the base C D. Hence, by the first part of I. 26, the triangles E A C and F C D are equal to one another in all respects, and, consequently, the side A E is equal to the side C F. But by I. 34, C F is equal to E B. Hence A E is equal to E B. Hence A B is bisected in E.

Lemma.—If two straight lines which meet one another are respectively parallel to two other straight lines which meet one another, then the angle contained by the first pair is equal to that contained by the second.

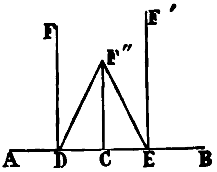
Let A B, B C be the first pair, and D E, E F the second, A B and E F, if produced, will meet. For if not, A B would be parallel to E F, and hence, by I. 30, D E would also be parallel to E F, which is impossible, since, by hypothesis, D E meets E F. Let A B and E F meet in H. Similarly, B C and E D must meet, say in G. Now, by I. 29, the angles A B C and D E F are each equal to the angle B H E, thereforethey are equal to one another.



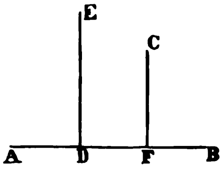
I. 23.—Let D be the given angle, B C the given straight line, and A the given point; from A draw A E and A F parallel respectively to the lines containing D. Then the angle E A F is by the preceding lemma equal to the angle D. Take any length A G from A C, and cut off A E equal to A G. Join E G, and let E G meet A F in H, make G K equal to E H. Then, since A E is equal to A G, hence the angle A E G is equal to the angle A G E. By I. 4 it can easily be proved that the triangles A E H and A G K are equal in all respects. Hence the Angle G A K is equal to the angle H A E, which is equal to the angle D.



I. 11.—Begin as in Euclid, taking C D equal to C E. Through D draw D F, making any angle with A B. Through E draw E F', making an angle C E F' equal to C D F. If D F and E F' do not meet, then they are parallels, and by I. 29 F D E and F' E D are both right angles. In this case it is only necessary to draw (by I. 31) a line through C parallel to D F' or E F', which shall be at right angles (by I. 24) to A B. If, however, D F and E F' meet, let them meet in the point F''. Join F'' C. C F'' is at right angles to A B. For, since the angles F'' D E and F'' E D are equal, hence by I. 6 F'' D is equal to F'' E. Hence it is easily proved by I. 8 that the angles F'' C D and F'' C E are equal to one another, and, consequently, F'' C is at right angles to A B.



I. 2.—Take any point D in A B, and erect D E at right angles to A B. If D E passes through C, the problem is solved. If not, through C draw C F parallel to E D, meeting A B in F. C F is perpendicular to A B. For by I. 29 the angle C F B is equal to the angle E D B, hence it is a right angle.



I. 18, I. 19, I. 20, and I. 21, can now be proved as in Euclid.

The same is true of I. 24, I. 25, and the second part of I. 26.

Propositions I. 35 to I. 49 also follow as in Euclid.

It will be observed that all the propositions of the first book of Euclid have been demonstrated, with the exception of the first and the twenty-second propositions. Of these the former is a particular case of the latter.

It is evident that the whole of the second book, with the exception of the last proposition, can be proved exactly as in Euclid.

VII.—*On Daltonism.* By Wm. Ramsay, Ph.D., Secretary of the Chemical Section.

[Read before the Society, January 7th, 1880.]

Although colour-blindness has been made the subject of numerous observations, which have become the basis of several theories having for their object the explanation of this curious phenomenon, a few facts which have come under my notice may be thought worth recording. The subject of the experiments was a gentleman attending my class last winter. My attention was first directed to his achromatopsia by his failing to see any difference in appearance between crystals of bichrome and red prussiate of potash, and, after some inquiries, I learned that he was nearly totally colour-blind. The usual inability to distinguish red from green was easily proved; that his was an extreme case, moreover, was shown by his noticing no difference of colour, but only of intensity, in any colours except blues. These he at once distinguished; and any colour which had a shade of blue, such as pink, he classified as blue. The observations I made on him may conveniently be classed under three headings—

(1) The sensations excited by polarized light;
(2) Those excited by fluorescent solutions; and
(3) His range of vision as regards colour.

(1) *Sensations excited by polarized light.*—On requesting my

colour-blind friend to arrange a number of coloured wafers, and to place together those which to his eye appeared to resemble each other, he said that he would first pick out all the blue ones. This he did, but among the number were several pink wafers, which to my eye conveyed only a faint sensation of blue. He then arranged the remainder, according to their intensity of shade, placing them in the following order:—Black, brown, chocolate-coloured, maroon, bright scarlet (among them some brilliant green wafers), bright green (with one or two scarlet wafers), orange, yellow, white. I drew his attention to the green wafers which he had placed among the scarlet ones, and suggested that they belonged to the class of green, without, of course, naming the colour. He compared them carefully, and finally decided to leave them among the scarlets. I then made him arrange coloured silks, with the same result. Wishing to ascertain whether such colours, viewed by monochromatic light, altered their appearance to him, the colours were exposed to the brilliant yellow light of a spirit lamp in which salt had been placed. The result was precisely the same as before. He could still easily distinguish blues; he still confused reds with greens; and, in arranging the colours, he placed them in the same order as before. He declared that bright scarlet, which to an ordinary eye appears orange-brown in sodium light, underwent no alteration to his eye.

I then desired him to look through the eye-piece of a saccharometer, in which, by polarized light passing through quartz plates, all the colours are successively contrasted with their complementaries—the colour and its complementary each forming half of a disc; and in changing the colours to stop at the deepest shade. He remarked that all the colours appeared to him to possess the same intensity. I then asked him to show me a blue, and was considerably surprised to find that none of the shades appeared blue to him, although I could obtain what appeared to my eye a pure sky-blue. I even tried to persuade him that the colour was blue without being able to convince him in the least. It would therefore seem that he was incapable of distinguishing any colour produced by polarized light.

(2.) *Sensations excited by fluorescent solutions.*—Two solutions were shown to my friend—viz., acid-quinine sulphate and eosine. In gas-light the former produced no sensation on an ordinary eye, and simply appeared to be water. But to the colour-blind eye it appeared deep blue. To avoid any possibility of mistake, I procured a similar bottle, and filled it with water. But in every instance my friend pronounced the solution of quinine to be blue, and maintained that it cast a blue shadow on the wall. The solution of eosine appeared to him "dirty," and he pronounced it to resemble muddy water. This led me to inquire whether his range of vision of colour, as seen in the prismatic spectrum, differed from that of an ordinary eye, since it was evident that he could perceive colour which to an ordinary eye was quite imperceptible.

(3.) *Range of vision as regards colour.*—Before experimenting with the colour-blind subject it was necessary to get an average range. For this purpose I measured the range of vision of eighty individuals, using for the purpose a Browning's spectroscope with an arbitrary scale. Each person was requested to state the number on the scale at which he ceased to perceive violet light, and the corresponding number at the other end of the spectrum, at which red light disappeared. Of these 4 could see only as far as 190°, 12 as far as 200°, 7 up to 205°, 21 up to 210°, and the remaining 46 could appreciate colour at various points between 210° and 220°. The colour-blind subject distinctly perceived light up to 240° at the violet end of the scale. At the red end the average of observations with 80 different individuals was 81°, whereas the colour-blind eye was unable to distinguish light at a lower number than 85°. These observations require confirmation, and much more accurate measurement; but they seem to point to the presumption that the range of vibration which produces the effect of colour on ordinary eyes is different from that having the same effect on a colour-blind eye. Analogy may be found in the kindred domain of acoustics; for it is well known that there is considerable difference in the ability of ears to detect sounds of high pitch, and that one ear may distinctly recognize the tone of a musical note three or four tones above one in which another ear fails to detect any musical sound whatever. It is not inconceivable, but even probable, that individuals exist who are unable to perceive a portion at the extreme end of the violet of the spectrum, but on whom light, invisible to the ordinary eye beyond the red end of the spectrum, may excite sensations. It may also be the case that such instances have not attracted observation, for colour-blindness may not be a necessary sequence of this peculiarity. I trust that these remarks may afford a clue to the true reason of achromatopsia, and suggest a method of investigation to those to whom the subject is a more familiar one than to the writer.

VIII.—*On Experiments with reference to Change of Volume of certain Bodies on being melted.* By HENRY MUIRHEAD, M.D.

[Read before the Society, January 7th, 1880.]

IT will be in the recollection of the members that, the session before last, I communicated to the Society the results of some experiments by Mr. Whitley, of Leeds (see vol. xi., page 145). In that communication I very shortly stated why the experiments had been instituted. To make the matter clearer, I may state, a little less briefly, the views of Sir Wm. Thomson, which led to the experiments being entered on.

It was assumed that the earth, subsequently to being in a gaseous condition, was once a white-hot liquid mass throughout its entire extent, and that, in the course of some millions of years, it cooled so much that a crust formed over its surface very like ice on water or the shell round an egg. But, as the earth through radiation still continued to cool, it, of course, shrank in bulk interiorly, leaving the unsupported shell to crack into fragments. These broken fragments of solidified crust Sir William supposed to have been specifically heavier than the hot liquid underneath, and, therefore, to have sunk deeply in it towards the centre of the earth. The process of cooling continuing to go on, by-and-by a second crust came to form, which, as a matter of course, cracked also, and followed its predecessor into the depths of the molten interior. Thus, on and on went the process of cooling, crusting, cracking, and sinking, until, after some more millions of years, the sunken fragments that did not wholly melt, came to form a sort of interior irregular framework or scaffolding, which, reaching up nigh the surface, now supports the present solid crust on which we live. This crust being thus prevented from falling in, its shrinking only causes the wrinklings we call mountains and valleys, including the depths of lakes, seas, and oceans.*

In the course of his address to the Geological Society of Glasgow,†

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* *Report of the British Association for 1876*, part ii., page 8.

† *Transactions of the Geological Society of Glasgow*, vol. vi., page 38.

Sir William said that he was not aware of any experiment that had been made to determine the relative specific gravities of solid and molten bodies. Struck by this remark, I applied to my friend Mr. Whitley, and afterwards, at the desire of Sir William, I submitted to this Society and to *Nature* the results of his experiments. This gave rise to Mr. W. J. Miller, C.E., calling attention to experiments communicated by him to *Nature* (vol. xvi., page 23), in consequence of a previous communication of experiments by M. Centner, of Meisen (vol. xv., page 529). Both these gentlemen found that masses of iron of 7 lbs., though they sank in the molten iron at first, soon came up to the surface again; while masses weighing 28 lbs. did not reappear. Our talented member, Mr. J. B. Hannay, who has also experimented in this matter, has explained to me the reason why the larger masses do not come back to the surface. The larger mass takes longer time to heat interiorly, so as to swell enough to get buoyant, therefore sinks to the bottom and gets glued to it. If, however, after a little more heating the mass be detached from its anchorage by a rabble, it will rise and float like its smaller brethren.

In the course of a conversation I had with Sir William, last spring, he referred me to some writings of Gustav Bischoff as opposed to Mr. Whitley's results.* I told him I should ask Mr. W. to note, if he could, any change of volume in the metal as it got red-hot. The following is from a letter from Mr. Whitley on the subject:—

"Railway Works, Leeds,
"19th June, 1879.

"Dr. MUIRHEAD,
"Cambuslang, Glasgow.

"My Dear Sir,

"With regard to your request, and confirming my letter of 20th October last, I have gone carefully over a small series of experiments regarding the fusion and the solidification of metals. I found that in metals—say iron, copper, and zinc, and also in compounds of metals, as brass—that at the transition point from liquid to solid, on the globules giving place to crystallization, the total mass had a tendency to enlarge as the network of crystals is formed; also, that the said network of crystals stands the longest test of heat when the same crystalline structure is being reduced to liquefaction, the metals especially floating from the interior of the mass. This phenomenon, to my mind, is most beautiful and natural; because, when crystallization sets in, the heat survives in the centre, which retains liquefaction to the latest possible point of time—so much so that, in the case of a large mass, if you break through the first few layers of crystals, the contents of the interior will flow out freely. And, since the heat by outward crystallization is thus forced from the exterior, it follows that the elements of liquefaction will predominate at the centre, and will be the first to become operative when heat is again applied up to the point of liquefaction. Thus, we have the double phenomenon of expansion and contraction in the liquefaction and solidification of metals and their compounds; in other words, that if you break a pig of metal and submit it to a centre of steady but not too rapid heat, the piece being vertical and the heat even on the total surface, the mass will commence to expand till the crystals, liquefying, give place to globules, and that liquefaction will take place in the centre first. And this process continues until the force of gravity causes the liquefied mass to flow from the interior, till finally the outer wall-work of crystals succumbs to external pressure.* Hence all similar metals float on their surface; hence, also, expansion and contraction in their transition stages to and from a solid state.

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* I have searched through Bischoff's *Chemical and Physical Geology*, but cannot find any reference to the point at issue.

"Trusting I have made myself sufficiently clear, and that you are really enjoying the spring and still more anticipating the approach of summer, I am, my dear Sir, yours truly,

"JOSEPH WHITLEY."

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* In reference to my hypothesis as to the cause of the cross-jointing in columnar basalt (see vol. x., page 149 of our *Proceedings*), I may note that the crystallizing action taking place all round the circumference, as shown in Mr. Whitley's experiments detailed above, seems to me a tolerably cogent answer to Professor James Thomson's conclusion, that "Any idea that the cracking of the columns would have been simultaneously begun all round the circumference, and advanced to terminate in the centre, requires little more than to be brought before the mind for consideration to be rejected as untenable. There seems, then, to remain nothing to suppose but that the ordinary cross-joint fissures came first into existence in the interior of the column, and then flashed out thence towards the circumference."—*Transactions of Geological Society of Glasgow*, vol. vi., page 104.)

The foregoing, though most curious and interesting as a new fact, did not quite give me all I wanted. It happened, however, in August last, at the Sheffield Meeting of the British Association, that Mr. T. Wrightson, of Stockton-on-Tees, read a paper "On the Changes of Volume in Iron when passing from the solid to the liquid state" (see British Association Report for 1879, page 506). I quote therefrom and from abstract:—

"Cast-iron spheres were made of various sizes, and *lowered* into molten iron. They invariably went below the surface for a few seconds, then rose to sight, and continued rising gradually until their maximum expansion was reached. . . . . A cast-iron ball of known weight was suspended from a spring balance and dipped into the molten iron. Instead of being allowed to rise to the surface, it was kept down, and as the ball changed in volume it displaced more or less of the fluid iron; the flotation or sinking thus produced acted on the balance, and gave a means of registering the successive changes at intervals of time." Mr. W. experimented on various balls, and lays down graphically the results of his observations. "The following table shows the maximum variations of sinking or floating effect in percentages of the actual weight of the balls; also, the actual floating or sinking effect in ounces avoirdupois:—

Diameter of Ball.	Weight.	Maximum sinking effect.		Maximum floating effect.	
		Weight.	Percentage of whole Weight.	Weight.	Percentage of whole Weight.
3 inch, 1st Expt.,...	58½ oz.	2 oz.	3·4	7½ oz.	12·8
3 ,, 2nd ,, ...	59¾ ,,	2¾ ,,	4·6	5¼ ,,	8·8
4 ,, 3rd ,, ...	132¾ ,,	2¼ ,,	1·7	13¼ ,,	10·0
4½ ,, 4th ,, ...	182¾ ,,	2¼ ,,	1·2	13¾ ,,	7·5

"From the above it will be seen that the density of the ball in the first experiment varies from 3·4 per cent. below to 12·8 per cent. above the density of equilibrium, being a total change between the extremes of 16·2 per cent. This is the highest result. For the lowest it will be found that the 4½-inch ball (fourth experiment) has a variation of 7·5 per cent. above and 1·2 per cent. below the line of equilibrium, or a total variation of 8·7 per cent. of the weight immersed.

"From an examination of the table and others made by the author, it appears that, in passing from the solid to the liquid state, the density of the iron is at its maximum when cold, at its minimum when in the plastic state, and that the density when in its liquid state is between the two extremes, although much nearer the solid than the plastic density.

"The amount of expansion in Nos. 1 and 3 are much higher than subsequent experiments show, as the principal object of these two trials was to observe the state of the balls when pulled out immediately before liquefaction. At the time the balls were pulled out they appeared to have reached the highest point of expansion, and were, in both cases, so soft and uniformly plastic that the author was able to thrust a small pointed rod of wrought-iron through and through the mass, the consistence being similar to that of putty, and evidently just on the point of liquefaction."

After the present communication was read to the Society I received from Mr. Wrightson a paper, reprinted from the *Journal of the Iron and Steel Institute*, No. 11, for 1879. It contains an interesting account of a very much larger number of experiments on metals. The two paragraphs immediately preceding this are from it.

On going over the whole evidence available, I find myself forced to the conclusion that the results of the great majority of the experiments are not favourable to Sir Wm. Thomson's (or Hopkins') hypothesis that cooled fragments of the earth-crust would have descended deeply to arrange themselves as he has described.

But, furthermore, even supposing the earth to have been formed in accordance with the nebular theory, and that the mass was at one time molten throughout (which I take the liberty to doubt),* when such a large mass underwent the process of cooling for some millions, or even thousands of years, the materials of least specific gravity would be sent to the surface.. These lighter materials, on being solidified through cooling, so as to form a crust, on breaking into fragments would not have been permitted by the specifically heavier molten matters below to penetrate their bowels to any great depth. Cooled slag is never permitted to sink into molten cast-iron.

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* See *Proceedings of the Philosophical Society of Glasgow*, vol. x., p. 59.

IX.—*On the Volumes of Solid and Liquid Cast-Iron with reference to the Theories of Volcanic Action.* By J. B. Hannay, F.R.S.E., F.C.S.

[Read before the Society, January 7th, 1880.]

The examination of the volumes of substances at their freezing points in the solid and liquid states is of importance in the consideration of cosmic phenomena, and the fact observed by ironfounders that cast-iron, on solidifying, increases in volume, and that certain slags seem to do the same, is made the basis of a volcanic theory by Messrs. Nasmyth and Carpenter in their admirable work on the moon. Their proposition is as follows:—"The broad, general principle of the phenomenon here referred to is this: That fusible substances are, with few exceptions, specifically heavier while in their molten condition than in the solidified state. . . . It follows as an obvious corollary that such substances contract in bulk in fusing or melting, and expand in becoming solid. This expansion upon solidification is what now concerns us." Again, "It is a fact perfectly familiar to ironfounders, that when a mass of solid cast-iron is dropped into a pot of molten iron of identical quality, the solid is found to float persistently upon the molten metal—so persistently that, when it is intentionally thrust to the bottom of the pot, it rises again the moment the submerging agency is withdrawn." "This expansion of volume which accompanies the solidification of molten matter furnishes a key to the solution of the enigma of volcanic action; and that such theories depend upon the agency of gases, vapours, or water, are, at all events, untenable with regard to the moon, where no gases, vapours, or water appear to exist." Their theory is, then, that as the substances solidify under the crust, their expansion causes the bursting of weak portions of the solid surface, and thus give rise to volcanos. Subsequently, the authors write: "When the molten substratum had burst its confines, ejected its superfluous matter, and produced the resulting volcanic features, it would, after final solidification, resume the normal process of contraction upon cooling, and so retreat or shrink away from the external shell. Let us now consider what would be the result of this. Evidently the external shell or crust would become relatively too large to remain at all points in close contact with the subjacent matter. The consequence of too large a solid shell having to accommodate itself to a shrunken body underneath, is that the skin—so to term the outer stratum of solid matter—becomes shrivelled up into alternate ridges and depressions, or wrinkles." Thus the authors give two causes for the present configuration of the moon's surface—viz., expansion during solidification causing ejection of liquid or volcanic action, and shrinking of the interior solid owing to cooling after the crust has cooled causing "ridging" of the surface. Mallet, on the other hand, holds that no such expansion takes place on solidifying, and depends for volcanic energy on the falling in of the crust, as the planet cools the crushing force, giving rise to much heat, and this heat, by the intervention of water, giving rise to volcanic phenomena. To support this view Mr. Mallet, in a paper entitled "On the alleged Expansion in Volume of various Substances in passing by Refrigeration from the State of Liquid Fusion to that of Solidification," read before the Royal Society in 1874, gives the results of some experiments carried out to show that cast-iron does not expand upon solidification. In this paper he says:* "Considerable physical interest attaches to this subject, from the analogy of the alleged facts to the well-known one, that water expands between 39° and 32° F., at which it becomes ice; and a more extended interest has been given to it quite recently by Messrs. Nasmyth and Carpenter having made the supposed facts, more especially those relative to cast-iron and to slags, the foundation of their peculiar theory of lunar volcanic action as developed in their work, 'The Moon as a Planet, as a World, and a Satellite' (4to, London, 1874). There is considerable ground for believing that bismuth does expand in volume at a new consolidation; but, with respect to all the other substances supposed to do likewise, it is the object of this paper to show that the evidence is insufficient, and that, with respect to cast-iron and to the basic silicates constituting iron slags, the allegation of their expansion in volume, and therefore their (greater) density when molten is greater than when solid, is wholly erroneous." The latter part of the sentence, although not clearly put, and containing a word too many, which I have put in parenthesis, contains the point at issue. Mallet's method of settling the dispute was to pour into an iron vessel liquid cast-iron, and the contents of the vessel being known, data were thus obtained by which the density of the liquid and solid were obtained. All necessary corrections were made, and the results obtained were that the cold cast-iron had a sp. gr. of 7·170, the liquid 6·650, and that at the solidifying point there was no apparent expansion. Now, it is so well known by practical men that cast-iron *does* expand, that it seemed of some importance to find why this was not shown by Mallet's method. I had tried for me a number of experiments on this subject which I have communicated to the Royal Society of Edinburgh,* and of which the following is a summary:—In pouring cast-iron, at what Mr. Mallet terms a yellow heat—into an iron mould, unless that mould be very thick, it yields easily to the mass when solidifying—hence the volume of the vessel cannot accurately be determined, as the vessel yields not equally but at irregular points. The only method which can give satisfactory results is that of immersing solid metal of the same composition in a bath of the liquid. Mr. Mallet objects to this, as he says that solids float on liquids which are specifically lighter, but this never takes place when the solids have been immersed for some time below the surface.

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* *Chem. News.*

Mr. Mallet, to account for solid iron floating upon the liquid, calls in a new force—"repellant force"—and says "that its amount is, *cæteris paribus*, dependent upon the relation which subsists between the volume and 'effective' surface of the floating piece." I think that the experiments I am about to describe will dispel all uncertainty about the matter. Spheres of iron were cast from 3 to 6 inches in diameter, and their solidity determined by breaking one of a pair which weighed exactly the same. There were no hollows found, so that we had here a solid sphere of iron. A bath of the same metal was taken, about 4 feet wide by 2 feet deep, and one of the spheres dropped in. It sank immediately, and on raking the pot with a rod, it could be felt at the bottom. In about 50 seconds, however, it came to the surface, and had a temperature of dull red. As its temperature increased it floated higher and higher till it began to melt, when its height remained constant, and then, of course, diminished as the sphere melted away. Another experiment was done with the same results, and the value was found to be constant. Some spheres were then floated and fished out when at their maximum temperature, and the "tide mark" left by the contact with the liquid surface showed the relation between the volume or densities of liquid and solid metal.*

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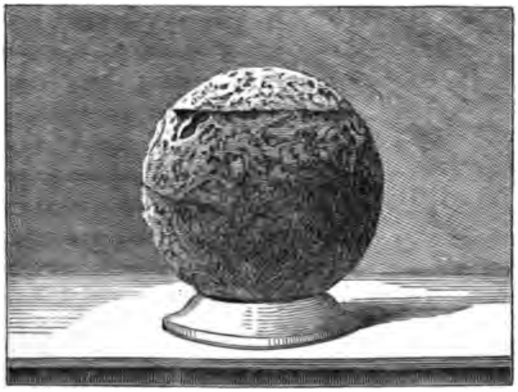
* Read at the Meeting on 15th December, 1879.



Thus it is plain that cast-iron does expand upon freezing. The results obtained are stated in the paper, and were found to be that on an average cast-iron expands 5·62% of its volume on solidification. This might seem sufficient to set the matter at rest, but I have attacked the problem in another way, which proves the above. It was noticed that the temperature at which the cast-iron spheres floated level with the surface of a bath of similar metal was a dull red heat, and a large number of experiments were made by heating cast-iron spheres to various temperatures and plunging them in the molten metal. By this method the other result was confirmed—viz., that the iron just floats, touching the surface of the liquid at a red heat, estimated to be at 750° to 800°. Now, it remained to determine the expansion up to that temperature, and this was done by observing its linear expansion in the usual apparatus—where the expansion of a bar of metal deflects a telescope—and calculating the cubical dilation. A bar of cast-iron was placed on such an apparatus and surrounded by live charcoal, and when its temperature was raised (as nearly as could be judged, the same temperature as that at which the iron floated) its expansion was read off.' Four experiments gave as follows:—·000055,

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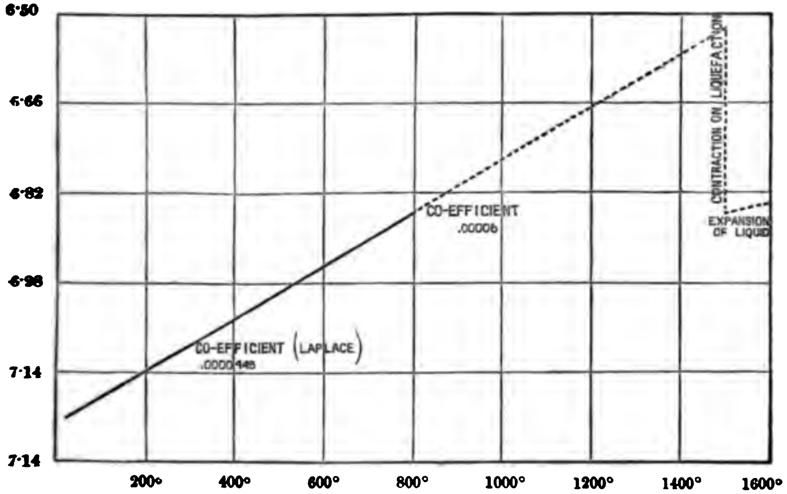
* See Woodcut from Photograph.

·000070, ·00005, and ·000065, giving a mean of ·000060 per degree centigrade. The density of the iron I experimented with was 7·214, which decreased to 6·883 at about 800°, and this was the density of the liquid; but as a sphere floated with 5·62% of its volume above the liquid, the density of the solid at its fusing point must have been reduced to at least 6·535. I say at least, because as the experiments had to be done with iron considerably above its fusing point, in order to prevent its freezing while the experiments were being conducted, the result is under the truth. Now, Mr. Mallet's iron had a density of 7·170 solid and 6·650 liquid, and supposing that the co-efficient of expansion did not increase (which is very unlikely), his own would be reduced to 6·56 at 1500°, which shows that the iron would have floated. A curve appended illustrates the expansion.

Mr. Mallet admits that the metal bismuth does expand on freezing, and this I find to be the case, although, as far as I can determine, to a slightly less extent than cast-iron, the estimates I have made giving 4·8% as the amount of expansion on solidifying. Mr. Mallet instances lead as a proof that iron does not float, but it has long been well known that solid lead does not float, as it has also been known that iron does. On page 216 Mr. Mallet says, in regard to the causes of flotation: "B. A repulsive force of some and tending to repel the surfaces in contact with the hot and cold, metals," and goes on to explain this, but one experiment like the following must at once dispel all such theories:—A sphere of solid cast-iron, 6 inches in diameter, was placed in molten iron, and at once sunk, but after about 40 seconds floated again. When it reached its melting point it was washed with molten metal, and every part of it thoroughly "wet" with it, as was seen by it forming a meniscus at the line of flotation, no matter what side was turned up, and this was continued persistently till the whole sphere was melted. Now Mr. Mallet might just as well try to explain the floating of ice on water by a "repellant force" as explain this floating of iron. Why, also, if iron floats by repellant force, does not copper do the same?

Further, from a letter published in the *Proceedings* of the Philosophical Society of Glasgow, it appears certain the slags, and even molten granite, show the same phenomenon—the solid floating on the liquid; and from experiments I have done at blast-furnaces on the Clyde, I have invariably found the same result, but have had as yet no opportunity of making measurements.

Meanwhile, Messrs. Nasmyth and Carpenter's theory, that there are two causes—expansion and contraction—for the present configuration of planetary and lunar surfaces, seems to be probable, Mr. Mallet's refutation of that theory, by his experiments upon iron, being unsound. As it appears unlikely that the telescope will ever reveal to us the action of the first of those volcanic forces (those planets which are still hot, Jupiter and Saturn, being enshrouded in clouds of vapour which will form their seas), we must look to the laboratory as likely to yield us the true explanation of the configuration of the surface of a mass cooled from fusion. In relation to the annexed curve, it appears that the rate of expansion does not increase very much at high temperatures; but, as I have explained, this is in part owing to the measurement of the expansion being low. Mr. Mallet's numbers cannot be taken as very accurate, owing to the plasticity of the containing vessel at a "yellow" heat.



X.—*An Experimental Investigation into the Trap and Water-closet System, and the relation of the same to Sewage Products, gaseous and other.* By NEIL CARMICHAEL, M.D., C.M., Fellow of the Faculty of Physicians and Surgeons, Glasgow, one of the Vice-Presidents of the Biological Section of the Philosophical Society, &c.

[Read before the Society, February 18th, 1880.]

"A GOOD water-closet is the only appliance fit to be used within a house, for by it all matters are at once conveyed away, and cease to have the power of producing evil so far as our houses are concerned." Such is the opinion expressed by one of our ablest sanitary engineers, Mr. Baldwin Latham.* This opinion is, however, not acquiesced in by all sanitarians, some asserting that the water-closet system is essentially erroneous in principle, and a serious source of danger. Opinions have been freely expressed on both sides of the question without leading to any very definite conclusions. As a matter of this sort could only be decided on careful consideration of evidence obtained by accurate experiment, I set myself to do what was in my power to settle the points at issue, as matters of fact. But before detailing to you the methods and results of this research, permit me to refer, as briefly as possible, to some points in relation to the water-closet system which it will be necessary clearly to comprehend before the objects and the value of the results obtained can be duly appreciated.

The form of water-closet most generally used, and the one almost exclusively used in Glasgow, is known as the pan closet. It consists of an earthenware basin, a copper cup or pan placed under the latter and containing water so as to close the lower end of the basin, a large iron trunk or receiver, and a syphon trap; the trunk rests on the floor of the apartment, the trap is under the floor. (See Fig. I.) On the floor under the trunk is a wide metal tray, the safe, designed to catch any overflowing or leaking water or slops, and convey these into the soil-pipe. The trap leads into the soil-pipe, which usually passes down through the house, and in the case of tenements through several houses, to the drain, which frequently passes under the floor of the house to the sewer. Usually, bath, kitchen sink, and wash-hand basins discharge into the same soil-pipe. These pipes are variously—indeed, very variously—trapped and ventilated. With such an arrangement, is it the case that when excreta have passed through the closet and through the trap, they "cease to have the power of producing evil so far as our houses are concerned?" To determine this we must first find what is the condition and what are the contents of the soil-pipe, the drain, and the sewer, and then proceed to determine what and how much, if any, of the contents of these pipes gain entrance to our houses under ordinary conditions. Solid and liquid excreta placed together and supplied with water rapidly putrify, and give off foul gases and particles. Sewage decomposed in the laboratory, under a bell jar, without access of

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* *Sanitary Engineering,* by Baldwin Latham, p. 506. Second Ed. 1878.

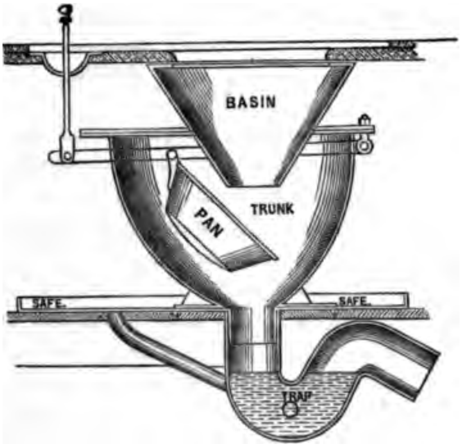

Fig. I.

air, gave off, in an experiment by Dr. Letheby, gases in large quantity, consisting of—

Marsh Gas,	73·[illegible]	per cent.
Carbonic Acid,	15·[illegible]	„
Nitrogen,	10·187	„
Sulphuretted Hydrogen,	0·[illegible]	„
	100·[illegible]	

In our sewers, however, the flow of liquid is too rapid, and the supply of air too abundant to allow of any such complete decomposition. Sewage, supplied with air as it is in our sewers, drains, and soil-pipes, gives off little, if any, marsh gas, sometimes a little sulphuretted hydrogen, a little ammonia, some nitrogen, and a considerable amount of carbonic acid, besides a very little putrid organic vapours and particles. The gases mentioned are sewage gases. And here let me say that I wish to restrict to their proper spheres the terms "sewer gas" and "sewer air." Sewer air is the atmosphere of sewers; sewer gases are the gases evolved from decomposing sewage. The atmosphere of sewers, drains, and soil-pipes is really ordinary atmosphere, plus less than one per cent. of the gases, vapours, and particles given off by decomposing sewage. An abundant supply of water, a rapid flow, and free ventilation render the air of sewers not greatly different in its chemical composition from the air we breathe; and only the worst sewers, choked up, stagnant, unventilated, are in any chemical sense highly poisonous. An instance of the worst sewage air,* found in a choked sewer in Paris, is given in the Table (I.). This is undoubtedly poisonous; such, however, is a very extreme case. The ordinary composition of sewer air may be considered fairly represented by the figures given in the table, representing the result of over sixty analyses performed by such men as Dr. Letheby, Dr. Miller, of London, and Professor Nichols, of Boston. The figures are condensed from a table in Buck's *Hygiene*. From the table it will be seen that, in its chemical composition, average sewer air is not very different from ordinary atmospheric air; that

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* This was *not* really a sewer air, but was the air over an immense accumulation of filth in a choked sewer, evolved while the mass was being stirred up. See Dr. James Adams on the *Sanitary Aspect of the Sewage Question*. Maclehose, Glasgow, 1868.

I.—TABLE ILLUSTRATING THE COMPOSITION OF SEWER ATMOSPHERE.

ATMOSPHERE.	AUTHORITY.	PER CENT.						
		Oxygen.	Nitrogen.	Carbonic Acid.	Sulphuretted Hydrogen.	Marsh Gas.	Ammonia.	Other Ingredients.
Bad Sewage, completely decomposed: air excluded, - -	Letheby, - -	...	10·187	15·899	00·81	73·833	...	...
Choked Sewer in Paris, - - -	G. de Claubry, -	13·79	81·21	2·01	2·99 (?)	...	...	Putrid organic vapours and particles, putrefactive germs, spores of fungi, etc.
Ordinary sewer air. Average of over 60 analyses, - - -	Condensed from Buck's *Hygiene*,	19·95	79·69	0·36	Traces sometimes	Traces once.	Traces	
In best of these, - - - -	Do.,	20·79	...	0·13	...	...	...	
Air of Scotland, - - -	R. A. Smith, -	20·96	...	0·0336	...	...	...	...
Limit of Purity, - - - -	Pettenkofer, -	...	...	0·100	...	...	...	...
	R. A. Smith, -	...	...	0·070	...	...	...	...
Expired Air, - - - - -	Foster, - -	16·033	79·557	4·380	...	...	...	...
Standard Theatre, London, 11.15 P.M., - - - - - -	R. A. Smith, -	...	...	0·320	...	...	...	...
School Rooms (exceptionally bad),	Pettenkofer, -	...	...	0·720 1·200	...	...	...	...
English Mines (average of 339), -	R. A. Smith, -	20·26	...	0·785	...	...	...	...
London Sewers, - - - -	Letheby, - -	19·506	79·962	0·532	under 0·0016	...	...	...

it is better than the air occasionally breathed in school rooms, mines, and theatres, in respect of the amount of carbonic acid contained in it, and much better than the air exhaled from the human lungs. Still it is not even in a chemical sense uninjurious; it is prejudicial to health if breathed undiluted. A man exhales 400 litres of carbonic acid in twenty-four hours. Ordinary sewer air contains 0·36 per cent of carbonic acid; expired air contains 4·38 per cent.,—that is, more than ten times as much. Sewer air would, therefore, require to flow into a house at the rate of 4,000 cubic feet per twenty-four hours to contaminate the atmosphere with carbonic acid (the gas most abundant in sewer air) to the same extent as one man. It is clear, therefore, that it is not the carbonic acid of the sewer air which produces the injury to health acknowledged to result from the breathing of sewer air. It is not the deficiency of oxygen, because this is affected even less by the entrance of sewer air than by the breath of one man. It does not lie in the presence of such gases as sulphuretted hydrogen, marsh gas, or ammonia, because these are present in such minute quantities as to be quite harmless, especially when diluted by the air of a house.

But besides the gases there are also found fœtid organic vapours and organic particles, living and dead. Dr. Parkes, in his work on Hygiene,* says "The organic vapour is carbo-ammoniacal; the putrid substance in the sewer water appears, from Odling's observations, to be allied to the compound ammonias; it contains more carbon than methylamine ($NH_2(CH_3)$), and less than ethylamine ($NH_2(C_2H_5)$)." The vapour, however, is present in sewer air in very minute quantities. Dr. Parkes † says "the analyses of Letheby and Miller have shown that generally the amount of carbonic acid is very little in excess of that in the external air, and that there is hardly a trace of sulphuretted hydrogen, or of fœtid organic effluvia." To these vapours, then, we cannot attribute very injurious effects on health. But besides the gases and vapours, there also exist organic particles living and dead; spores of fungi, bacteria, dead organic particles partially decomposed. The opinion is now pretty generally received that it is amongst this group that we must seek for the causes of the injurious effects on health which flow from inhalation of sewer atmosphere. When particles emanating from persons suffering from infectious diseases, especially infectious diseases mainly located in the bowels, as typhoid fever, enter a house with the sewer atmosphere, they constitute a source of great danger to health and life. The substances which convey infection from the sick to the healthy consist, so far as known to us, of minute masses of organic particles. They are particulate, to use the expression of Dr. Burdon Sanderson. The present state of medical opinion on this subject is accurately expressed by Dr. J. B. Russell,* the Medical Officer of Health for our city, when he says that, "observation and experiment . . . point with perfect certainty to this conclusion, that the infecting element in all specific and transmissible diseases is an organized solid, something having weight and dimensions." Dr. Alfred Carpenter,† in *Preventive Medicine and Public Health*, says, "all contagia are neither ætherial nor gaseous; that they are in themselves particulate." Similar opinions might be quoted from many others, but it is unnecessary.

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* Parkes' *Practical Hygiene.* Fifth edition, p. 108.

† *Ibid.*, p. 126.

The particles ordinarily found in sewer air are not emanations from infectious diseases, and are not capable of originating such diseases. A few years ago it was readily accepted that the inhalation of the gases and particles of a sewer atmosphere was a sufficient cause of such diseases as typhoid fever, dysentery, diarrhœa, scarlet fever, measles, cholera, diphtheria, and many similar. Recently, and from many quarters, this doctrine has been assailed. It has been shown that such diseases as have been attributed to the sewer atmosphere as their cause, are not much, if at all, more common amongst men working in sewers than amongst others; that choked or leaking sewers, drains, and soil-pipes, frequently produce serious injury to the health of those subjected to the influence of their exhalations without producing specific or infectious diseases; that the introduction of a proper system of sewerage has materially reduced the death-rate from those diseases; and, more particularly, careful and comprehensive investigations of recent epidemics of the diseases referred to, and of their modes of propagation, have demonstrated that the medium through which the poison was carried from the sick to the healthy was some article of food or drink, and not sewer air, unless exceptionally, and in these exceptional cases the sewer air has usually been found to have been recently contaminated by infected excreta. The specific poison was to the sewer foreign matter.

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* *Lectures on Public Health.* Russell and Wallace, p. 11. Maclehose, Glasgow, 1879.

† Dr. Alfred Carpenter. *Preventive Medicine and Public Health*, p. 221.

Dr. B. W. Richardson, F.R.S., says,—"Some think typhoid fever and cholera may be communicated in this manner; but I must candidly admit that in all my own inquiries on those diseases, and in this mode of communicating, I have not been able to satisfy myself that the poison was actually conveyed by the air."* Dr. Duncan, of Crosshill, as the result of a careful scrutiny of the conditions under which the epidemic of typhoid fever was propagated in 1874, was led to believe that "under ordinary conditions, sewer gas would not propagate the disease, even when typhoid excreta were present in the sewers."† There can be no doubt, however, that, under certain circumstances, such as the connection of the soil-pipe with cisterns supplying drinking water, the excretions of a typhoid patient entering the soil-pipe or drain may so contaminate the neighbouring houses as to set up in them the same disease. Such cases certainly occur. Contamination through the sewer itself, however, is not by any means so common, if, indeed, it ever occurs in the case of any moderately well ventilated sewer, so that it has come to be a tolerably well established opinion that any extended outbreak of typhoid fever in a district is to be attributed to other causes than the sewer connection. The poison in the excretions of a typhoid patient, added to a collection of putrid matter in a midden, soil-pipe, or drain, seems to multiply indefinitely, and perhaps at the same time to become intensified in virulence. The power of typhoid fever-tainted atmosphere to infect is, however, very slight, as compared with the power of the tainted liquid portion of the sewage; and the ingestion of any article of food or drink so tainted will infect with much greater readiness and certainty than the atmosphere of the apartment into which the patient discharges the poison, or than the atmosphere of the soil-pipe into which this poison is cast. But although specific or infectious diseases are not produced by ordinary sewer or soil-pipe atmosphere, many forms of ailment result from its inhalation. Headache, sickness, diarrhœa, sore throat, and general deterioration of health, and in fact a general lowering of vital resistance to disease, especially infectious disease, are very frequent results of breathing, for any long period, sewage contaminated air. And finally, on this point, What can be said statistically as to the effect of the connection of the house with the sewer on the death-rate from general and from specific diseases? Fortunately for us, an excellent address, delivered by Dr. J. B. Russell in 1877, in his capacity of president of the sanitary section of this Society, supplies us with valuable information on this matter. The whole address, which is printed in the *Proceedings* of our Society,* I would advise all interested in this subject carefully to study. Dr. Russell, in dealing with certain statistics relating to Edinburgh for 1871, demonstrated that diphtheria caused more deaths, in proportion to the general death-rate, in those places which were abundantly supplied with water-closets, than in those more sparingly supplied. In four groups into which the city was divided, it was found that the water-closet supply within the houses was 9½, 37, 73, and 88 per cent., and the death-rate from diphtheria was, per 10,000 deaths from all causes, 21, 23, 38, and 39. The death-rate from diphtheria, therefore, rose with the increase of water-closet accommodation, but by no means in the same proportion, for while the increase of water-closets reached 826 per cent. of the smallest, the largest death-rate was increased only 85 per cent. In dealing, however, with statistics of our own city, more valuable results were obtained. In houses of one apartment, having no water-closet or sink, a death-rate from diphtheria of 120, and from enteric fever of 249 per million was found. The introduction of a sink increased the death-rate from diphtheria to 253—*i.e.*, 110 per cent., and from enteric fever to 677—*i.e.*, 171 per cent. Under the same circumstances, the death-rate from diarrhœa was increased 104 per cent., and from croup, 93 per cent. From this we see that the introduction of a sewer connection by a sink increased materially the death-rate from the specific diseases diphtheria and enteric fever, and from general diseases, as represented by diarrhœa and croup; the effect, therefore, was a general increase of disease, most marked in diphtheria and enteric fever. In two-apartment houses the increase in death-rate from diphtheria and enteric fever was even greater, and in them the maximum was reached. In larger houses the death-rate from those diseases declined. From these facts it is evident that the presence in the house of a sink or water-closet, especially in a small house, is an important factor in the multiplication of those two specific diseases, and in the production of general diseases. That they are not essential factors is, however, evident from the large number of deaths from those diseases which occurred in houses having no such conveniences. I think the relation may fairly be considered as equivalent to the effect of overcrowding in the production of typhus fever and general diseases. Overcrowding seems to produce in the individuals subjected to its influence, and in their houses, the conditions best suited for the multiplication and spread of typhus fever, and to produce a general deterioration of health. A sewer connection in a small house seems to produce the conditions best suited for the spread of typhoid fever, and for the production of a somewhat similar deterioration of general health. Few would now venture the opinion that overcrowding is alone sufficient to originate typhus fever; and as little is it proved, I venture to say, that a sewer connection is alone a sufficient cause of enteric fever or diphtheria. It may appear to many of you that I have occupied too much of your time in the discussion of these preliminary matters. My excuse is simply that it is necessary to a clear conception of the results experimentally attained.

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* *Sanitary Engineering*, Baldwin Latham, p. 312.

† Maclehose, Glasgow.

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* *Proceedings of the Philosophical Society of Glasgow*, vol. xi., p. 8.

How do the water-closet and sink connections produce the evil effects which have just been considered? How do the contents of soil-pipe, drain, or sewer, obtain entrance to houses? In many ways. Suffice it that we mention a few, and refer those interested to such an excellent work as Dr. Teale's *Pictorial Guide to Sanitary Defects.** The worst form of contamination is that in which there is actual leakage of sewage into some portion of the house. This frequently results from defective joints or cracks in the pipes. The sewage may then lodge under the floor or in the walls, decompose, and send into the house foul gases, spores of fungi, putrefactive germs, and decaying organic particles. Contamination of drinking water of a cistern is another source of great danger. Perforation of soil-pipes was pointed out by Dr. Fergus, our worthy President, as a very frequent source of the contamination of houses with sewage atmosphere.† The inner surfaces of old lead pipes are found thickly encrusted, especially on their upper aspects, with a white powdery mass, the lead being reduced often to a mere film and very frequently perforated with numerous holes. Through these holes the atmosphere of the pipe is pressed into the house by every elevation of temperature in the pipes, and is drawn in by every fire burning in the house. An almost constant flow into and through the house of sewer gases and particles may be thus produced. This is a very frequent and a very serious source of danger; and to Dr. Fergus is due, for detecting and correctly interpreting it, the thanks of all interested in sanitary matters. Defects of the water-traps employed to exclude the sewer atmosphere frequently permit contamination of houses. Frequently the waterlock is insufficient, so that the resistance to the entrance of gases is too slight to exclude them. This insufficiency of waterlock may be due to defects in the construction of the trap, or may be caused by placing the trap at such an angle as to lessen or altogether abolish the waterlock. But a trap with a sufficient waterlock may be rendered inefficient, by syphoning through running the pipe full bore. But besides this, it is found that gases do come through a sound water-trap. Dr. Fergus discovered, and pointed out this fact, demonstrating it by some simple experiments performed before this Society.* These experiments were performed with glass tubes, so bent as to form a trap. Water was placed in the bend; the gas experimented with was placed in the lower limb; and the test employed was placed in the upper limb. The gases were found to pass through the water, and were detected in the upper portion of the tube. Ammonia was detected in 15 minutes, sulphuretted hydrogen in from 3 to 4 hours, and carbonic acid in 1½ hours. When the tubes were ventilated, the time of transmission was slightly increased. These facts Dr. Fergus has established beyond question. What, then, is the bearing of these facts on the point now under consideration? To what extent do the contents of the soil-pipe come through a sound water-trap? In the experiments just quoted the gases employed were presented to the under surface of the water in a very concentrated condition, probably not under 50 per cent. Under these conditions it required 15 minutes for ammonia to pass through in the most minute quantity that could be detected, 1½ hours for carbonic acid, and from 3 to 4 hours for sulphuretted hydrogen. How long would it take for these gases, greatly diluted with air, to pass through? How will it be with carbonic acid, one part in 1,000, with ammonia, one part in 500,000, and with sulphuretted hydrogen, one part in 700,000? This might be settled by performing experiments with gases so diluted, in glass tubes of the kind referred to. I think, however, that we will arrive at a much more reliable and more valuable answer by experimenting directly with soil-pipe gases and ordinary soil-pipe traps. To settle this point, experiments were performed with an ordinary water-closet syphon trap in actual connection with a house soil-pipe. The water-closet was an old one which had been in use for a number of years. It was situated on the ground flat. The soil-pipe into which it discharged was found, on examination of its internal surface, to be very foul. Into the same soil-pipe three water-closets of the houses above discharged. From the upper extremity of this pipe a two-inch ventilating pipe passed through the roof to the outer air. The lower end of the soil-pipe passed untrapped and unventilated into the drain. The drain discharged into the main sewer of South Portland Street, about 300 yards from its outlet into the river. The mouth of this sewer is submerged by the river at full tide, so that sewer gases tend to be pressed back towards the houses. The conditions here mentioned seem perfectly suited for test experiments. From this closet the basin, pan, the iron plate covering the receiver, and the handle and cranks were removed. A zinc plate was screwed down over the top of the receiver, the rim being first thickly covered with putty. (See Fig. II.) The holes in the side of the receiver, through which the cranks worked, were also closed with putty. Through this zinc cover passed two lead pipes (P. 1 and P. 2), with stop-cocks. Into the cavity of the receiver these pipes projected about 4 inches; and on the outside they were about 8 inches long. The receiver was ascertained, by testing with a manometer, to be air-tight. In the adjoining kitchen, near the sink, was fixed a metallic aspirator, in direct connection with the water-pipe. (See Fig. VI.) To describe the aspirator is unnecessary. Suffice it to say that the flow of water through this instrument produces a partial vacuum, and aspirates or sucks air through the side tube which extends to near the water-closet. On a stand beside the closet a series of six glass vessels, about 7 inches in height and 2 inches in diameter, are arranged. (Air washing apparatus, see Fig. II.) These have each an india-rubber stopper with two perforations, through which

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* *Dangers to Health.* T. Pridgin Teale, M.A. Churchill, London.

† *The Sewage Question.* A. Fergus, M.D. Porteous Brothers, Glasgow.

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* *The Sewage Question*, p. 11. A. Fergus, M.D. Porteous Bros., Glasgow.

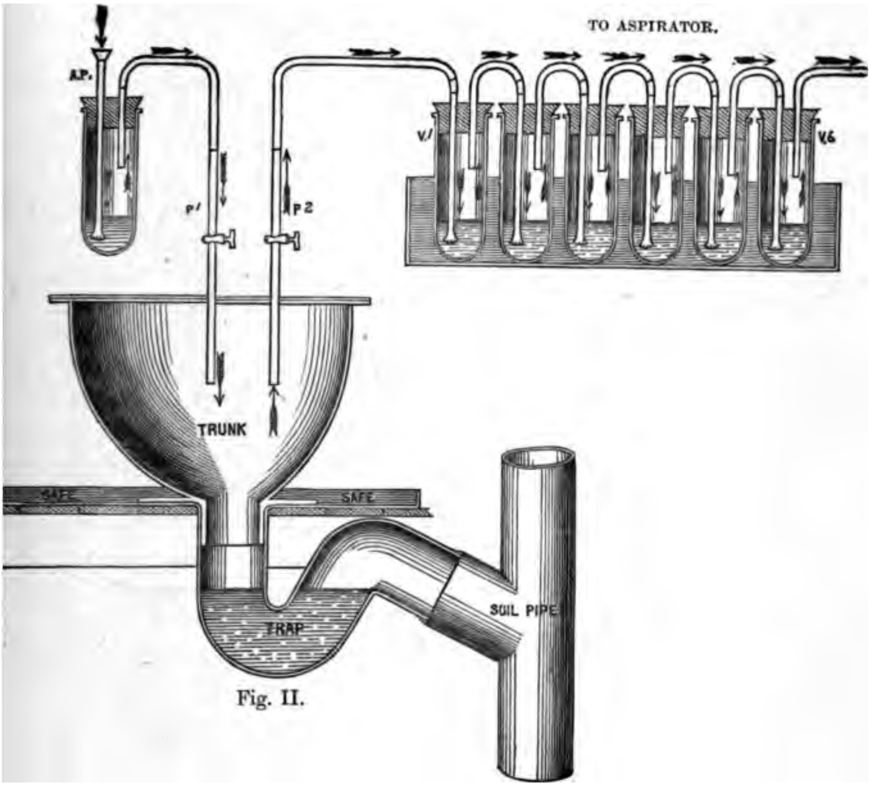

Fig. II.

pass glass tubes, one reaching to near the bottom of the vessel, and terminating in a rose, the other passing only a short distance into the vessel. The short tube of one flask is connected with the long tube of the next by a short piece of india-rubber tubing, so as to join the whole series. Another similar vessel (A. P.) is placed alongside these, but is not connected with them. The free dipping tube (V. 1) of the series is connected with one of the pipes (P. 2) entering the receiver, and the free air tube (V. 6) at the other end of the series is connected with the aspirator. The separate vessel is connected by its air tube with the other pipe (P. 1) of the receiver, the other tube of this vessel being open to the air. The six vessels are charged with a liquid capable of retaining the particular gas to be estimated. The separate vessel is charged with a similar solution more concentrated. With this arrangement, it will be seen, that when the aspirator is working, the air of the apartment is caused to bubble through the liquid in the single vessel, from this to pass through tube (P. 1) into the cavity of the receiver or trunk; to pass out of this through the other pipe (P. 2), bearing with it whatever gases have diffused from the soil-pipe, through the water-trap, into this cavity; with these gases to bubble through the solutions in the six vessels; to pass, if required, through a gas meter for measurement; and, finally, to be discharged through the aspirator. The air entering the receiver by first bubbling through the solution in the air-purifying vessel is deprived of any of the gas to be tested for, which it may happen to contain. Thus, all the gases which come through the trap are arrested by the solutions in the six vessels. These solutions are retained and tested. And here I wish to state that the method is an adaptation to the peculiar conditions of my experiments of the method of air analysis devised by our excellent Secretary, Mr. Dixon. For some valuable advice as to the methods of conducting the analyses I am indebted to Mr. Dunnachie, chemist, who succeeded Mr. Dixon, in conducting the analysis of the city.

The first gas to which I will refer is carbonic acid. The vessels were charged with a strong solution of caustic potash. The aspiration was continued for twenty-four hours each time. A measured portion of the aspirated potash solution from the six vessels was now placed in a Rohrbeck's carbonic acid apparatus and decomposed, being weighed in a delicate chemical balance before and after the escape of the carbonic acid. A large number of such experiments were made, of which an average statement is given in the Table (II.).

TABLE II.—QUANTITATIVE DETERMINATION OF GASES WHICH PASSED THROUGH WATER-TRAPS (A AND B) IN 24 HOURS.

	GAS.	OLD WATER-CLOSET TRAP (A.)	KITCHEN TRAP (B.)
		Grains.	Grains.
Soil-pipe Open at Top.	Carbonic Acid,... ...	7·084	7·084 10·470
	Ammonia, ...	$\frac{1}{217}$, $\frac{1}{250}$, $\frac{1}{330}$, $\frac{1}{400}$	$\frac{1}{100}$, $\frac{1}{200}$
	Sulphuretted Hydrogen	$\frac{1}{110}$	$\frac{1}{80}$
Soil-pipe Closed at Top.	Carbonic Acid, ...	32·032	17·063
	Ammonia, ...	...	$\frac{1}{400}$
	Sulphuretted Hydrogen	$\frac{1}{90}$	...

Putrid organic vapours, if present, are included in the Ammonia.

The details of one such case may be quoted as an example.

The charge distributed amongst the six glass vessels consisted of 100 cubic centimeters of a solution of caustic potash, of the strength 320 grammes per litre of water. The separate vessel (A. P.) was charged with a little of the same solution, into which a piece of caustic potash was placed. The aspiration was continued for twenty-four hours. The solution in the six vessels was now well mixed, and out of this 25 cubic centimeters taken for analysis. The 25 cubic centimeters of the aspirated solution were placed in a Rohrbeck's carbonic acid apparatus, which was charged with sulphuric acid. The apparatus was now accurately balanced. The sulphuric acid was then allowed to flow slowly into the potash solution, so as to disengage the carbonic acid contained. The apparatus was warmed and air drawn through it, so as to secure the evolution and escape of the whole quantity of carbonic acid which it contained. It was then allowed to cool, and again placed in the balance, the loss of weight being very carefully ascertained. The loss of weight represented carbonic acid—

25 c.c. of aspirated potash solution yielded	0·15	grammes	of CO_2.
Therefore the whole quantity (100 c.c.) of solution yielded 0·15 × 4 .. .	0·60	,,	,,
But			
100 c.c. of original potash solution yielded (tested in the same manner).	0·14	,,	,,
Therefore the quantity of carbonic acid received from the trunk was 0·60 − 0·14 =	0·46	,,	,,

So that in twenty-four hours 0·46 grammes, or fully 7 grains of carbonic acid passed through this water-trap. The amount of carbonic acid which passed through the water of trap into the receiver in twenty-four hours, in a large number of experiments, averaged a little over 7 grains.

For the ammonia testings the vessels were charged with dilute sulphuric acid, the solutions being tested by Wanklyn and Chapman's process.*

As an example the following is given:—The dilute acid after aspiration was neutralized by adding to it a solution of carbonate of potash. It was placed in a retort with water to make it up to half a litre, and from this 250 c.c. were distilled. This was tested by Nessler's process, and showed 0·125 millegrammes of free ammonia. To the solution remaining in the retort was added 50 c.c. of a solution, consisting of permanganate of potash 8 grammes, and caustic potash 200 grammes per litre. From this solution another distillation of 250 c.c. was made. This was similarly nesslerised, and showed 0·2 millegrammes of albumenoid or organic ammonia. The total ammonia, therefore, yielded by twenty-four hours' aspiration over the trap was 0·325 millegrammes—*i.e.*, about $\frac{1}{200}$ of a grain. In a large number of experiments the amount of ammonia varied from about $\frac{1}{400}$ to $\frac{1}{200}$ of a grain in twenty-four hours.

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* *Water Analysis.* J. A. Wanklyn, M.R.C.S. Trübner & Co., London, 1874.

For sulphuretted hydrogen the vessels were charged with permanganate of potash solution. In testing, the liquid was heated with the addition of a little nitric acid, and thus oxidized to sulphuric acid, and tested by bichromate of potash colour test. The amount of sulphuretted hydrogen which passed through the water-trap in twenty-four hours was about the $\frac{1}{100}$ of a grain.

These are the quantities of the only sewage gases existing in the soil-pipe, in estimable quantities, which pass through an ordinary water-closet trap in twenty-four hours. To make certain that these quantities are in no way peculiar to the particular trap used in this case, a fresh lead pipe trap was joined to the same soil-pipe, and brought through the wall into the adjoining kitchen. With this new trap (see Fig. III.), closed on the top by soldering over it a metal plate perforated with pipes as before, and similarly arranged for testing, results very closely agreeing were obtained. In this case the carbonic acid was from 7 to 10½ grains; the ammonia from $\frac{1}{200}$ to $\frac{1}{100}$ of a grain, and the sulphuretted hydrogen from $\frac{1}{80}$ to $\frac{1}{60}$ of a grain. As I have stated, the soil-pipe was ventilated only by a two-inch pipe carried from its upper extremity to the outer air. To test the matter under more severe conditions I caused this small pipe to be plugged by stuffing it tightly with paper, and again experimented as before. The amount of gas which then passed through the traps was decidedly increased but was still very small. The carbonic acid was increased to 32 grains in the old and 17 grains in the new trap. The ammonia was not materially increased in either. The sulphuretted hydrogen was increased in the old to the $\frac{1}{80}$ of a grain, in twenty-four hours. These are the quantities of the gases examined which passed through ordinary water-traps, from an unventilated soil-pipe. Diffused into the atmosphere of a house during twenty-four hours, these quantities are, from a health point of view, quite inconsiderable—perfectly harmless.

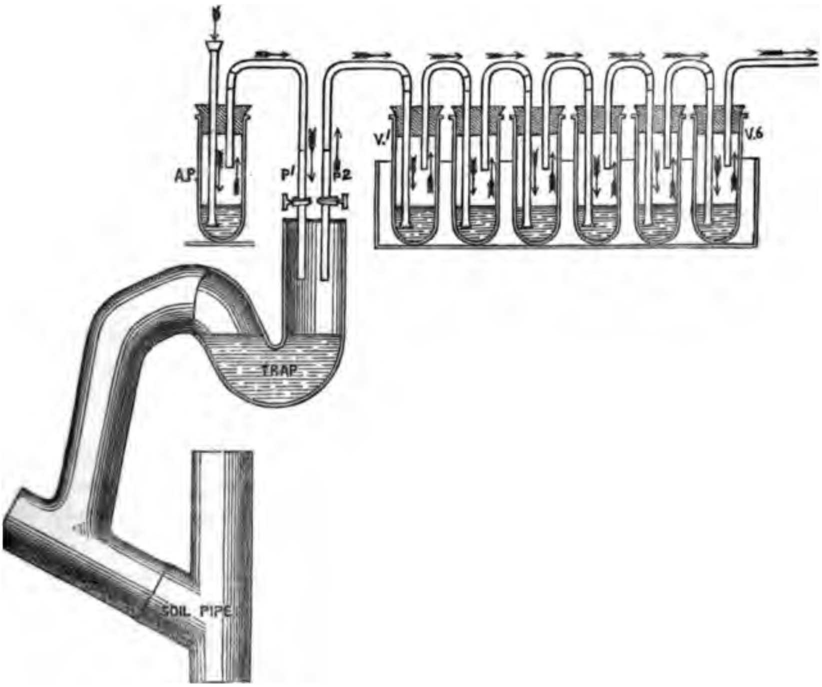

Fig. III.

32 grains (the largest quantity) of carbonic acid is less than the quantity of the same gas given off when a bottle of lemonade is drawn. A man exhales in the same time about 400 times the amount which passed through the trap from an unventilated soil-pipe. The $\frac{1}{100}$ of a grain of ammonia, and the $\frac{1}{60}$ of a grain of sulphuretted hydrogen diffused continuously through the atmosphere of a house during twenty-four hours, it need scarcely be said, are absolutely harmless. But do the fœtid organic vapours, of which we hear so much indefinite horror expressed, but of which so little is known, come through in appreciable amount? As we have already seen, there exist in sewer air mere traces of these vapours. For the detection and estimation of these, there is, so far as I know, no satisfactory chemical method. The sense of smell is, however, a very delicate test of their presence. I have very frequently asked medical and other friends to apply this test to the kitchen trap, and they have invariably failed to detect the sickly or fœtid odours, so readily detected in soil-pipe atmospheres. So that if these

vapours do come through, they do so in quantities too minute for the nasal organs to detect. We are able, however, to state in more exact terms something as to the quantity in which they may come through. These vapours are organic; as already stated, they are carbo-ammoniacal, they are therefore decomposed by Wanklyn's process for the estimation of nitrogenous matter as ammonia, and are, therefore (if they do pass through the trap), included in the ammonia; and consequently less (probably very much less) than the $\frac{1}{100}$ of a grain in twenty-four hours. This, I need scarcely say, must be harmless.

We now come to the much more important question—Do the organic particles—including germs, putrefactive or specific—come through a sound water-trap? A simple but very crude method of examining the question consists in the microscopical comparison of water through which soil-pipe air has been aspirated, with water through which the air over the trap has been drawn. The former contained numerous organic particles of a very heterogeneous kind; in the latter no particles could be detected. This method is, however, not conclusive, as particles might readily elude observation. This, however, leads us to consider what I will call the mechanical affinity of water for solid particles, especially organic particles. Dr. Frankland performed some beautiful experiments to determine whether particles contained in a liquid are given off from that liquid under certain conditions.* A saturated solution of lithic chloride, placed under a bell jar, did not give off any of that salt with the aqueous vapour rising from the surface of the liquid, the spectroscopic test being employed. And even violent agitation of this solution with a wooden rod, in a glass cylinder thirty inches high, did not raise any of the salt to the mouth of this cylinder. The bursting, however, of bubbles of carbonic acid in this liquid, caused the dispersion of the lithic chloride particles to some distance. The particles which enter the water-trap, not being subjected to the influence of any effervescence of gases generated in the trap, will, we should expect, be retained by the water and not given off to the atmosphere. In the published reports of the air analyses of Glasgow,† already referred to, we find figures which decidedly support this conclusion. From these reports I have made up Table III.

The sixth column gives the impurities found in the atmosphere

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* *Proceedings of the Royal Society of London*, vol. xxv., p. 542.

† *Report of the Air Analysis of Glasgow, Sanitary Department.*

TABLE III.—THE IMPURITIES OF THE ATMOSPHERE OVER THE CLYDE AT BROOMIELAW, AS COMPARED WITH OTHER PARTS OF THE CITY.

IMPURITY.			Stirling Square.	Calton.	Hospital, Kennedy Street.	Sailors' Home.	Western Infirmary.	Under Broomielaw Bridge.	AVERAGE.
Carbonic acid, - - - -	Parts in 10·000, - -		3·391	3·530	3·496	3·431	3·334	3·245	3·404
Sulphur as Sulphuretted Hydrogen,	Millegrammes in 100 c. feet		·31	·31	·34	·26	·16	·30	·28
Chlorine, - - - - - -	Do.	do.	·08	·08	·27	·06	·07	·05	·10
Nitrogen as Ammonia, - - -	Do.	do.	.110	·103	·064	·065	·050	·058	·075
Nitrogen as Albumenoid Ammonia,	Do.	do.	·078	·081	·076	·061	·062	·073	·071
Organic Matter, - - - -	Do.	do.	·188	·184	·140	·126	·112	·131	·146

over the Clyde, under the Broomielaw Bridge. The water of the river at this point I find, from a report submitted by our city analyst, Dr. Wallace, to the Magistrates and Town Council,* to contain of free ammonia 0·263 grains, of albumenoid ammonia 0·065 grains, per gallon. This, I need scarcely say, represents a very large amount of organic impurity.

It will be seen from the table that, notwithstanding this large amount of organic matter existing, as it does, in a semi-putrid condition, the air, a few feet over this water, is rather more free of impurities than the air of the Central and the Calton districts of the city—contains less organic matter. The mechanical affinity of water for particles prevents their dispersion from even a foul river. The organic particles are rendered so heavy by soaking with water that they are not raised with the aqueous vapour, or by wind blowing over the surface.† Marshes and swamps, in a dry season, when the water is low and the particles are drying on the muddy sides, and on the vegetation on the banks, are frequently highly pestilential. Mr. Baldwin Latham,‡ in his work on *Sanitary Engineering*, on this point says, "One thing is certain, with reference to malaria, that all authorities are agreed that it is never extricated from a water surface," &c. These methods of answering the question are, however, not quite conclusive, although they doubtless show a high probability in favour of the opinion expressed. I therefore set myself, by direct experiment, to determine the point. And the only method of experiment which can be considered conclusive, as to the presence or absence of germs, is the method of the cultivation test. Particles, far too few, and perhaps too small for microscopical detection and recognition, are readily detected and recognized by the method of cultivation. A liquid capable of cultivating any germs added to it, is placed in a glass vessel. The liquid and vessel are subjected to a temperature of not less than 212° F., for a sufficient term to destroy all life, active and germ. Into this medium is introduced the air or liquid to be tested for living particles, care being taken that, in the process, the cultivating liquid is not otherwise contaminated. The apparatus is now kept for several weeks, at least, in a room at cultivation temperature, say from 60° to 120° F. If the air or liquid introduced contains no germ or active life, the liquid remains clear and free from life. If, on the other hand, germs are introduced, these are cultivated and multiply enormously, so as to render the liquid opaque, and perhaps to produce large growths of fungi. The microscope must be employed to decide whether life has developed or not. The result is, then, simply either positive or negative; the liquid ferments or putrefies, or it does not; it contained germs or active life, or it did not. This method, it will be seen, is vastly more delicate than even the spectroscopic, of determining whether or not particles are dispersed from a liquid at comparative rest, in which they are contained. About five years ago, when experimenting on the germ theory of putrefaction, I performed the following experiment:—Into two glass test tubes (Fig. IV.), about four inches long, and having drawn out necks, I introduced turnip infusion. The liquid in the tube was then boiled to sterilize it; and while steam was freely issuing from the drawn out necks, a closed capillary tube, containing a putrid infusion, was passed into each tube. The body of each tube was then immediately dipped into cold water, and, at the same time, the neck sealed by melting it in the blowpipe flame. The putrid infusion in the capillary tubes was thus subjected to the boiling temperature for only a few seconds.

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* *Glasgow Sewage Reports*. By Dr. Wm. Wallace. 1879.

† Since writing this paper, I have received the "National Board of Health Bulletin" from *Washington*, United States, in which, in an article on "Organic Matter in Air," Prof. Ira Remsen details some very interesting experiments bearing on this subject, which are confirmative of the conclusions just referred to.

‡ Sixth edition, p. 425.

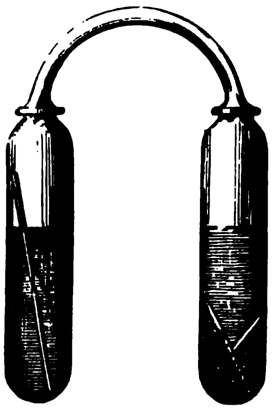

Fig. IV.

The necks of the tubes were now connected by putting over each, while hot, a piece of india-rubber tubing, which adhered. A small portion of the neck of each tube was now broken off within the tube, so as to open the communication between the two tubes. In this way the whole apparatus was sterilized, except that one capillary tube, in each larger tube, contained putrid liquid, and the two tubes had an open connection through the india-rubber tubing. The apparatus stood for several weeks unchanged. I now violently shook one tube so as to break the contained capillary at a constricted portion, and so inoculate the infusion. This putrefied, developed a large fungus, and became muddy from the development of bacteria. I watched for some time, and daily expected to find that the germs would pass over and inoculate the liquid in the other tube; but they have not passed over even in five years. These tubes I now show you. This experiment, which did not turn out as I had anticipated, directed my attention to the subject of the relation of water to the behaviour of putrefactive particles. Some points in this investigation I now place before you.

Into a glass flask (similar to flask in Fig. V.), with long neck bent so as to form a trap, and also into this trap, I placed urine. Both were sterilized by prolonged boiling. The liquid in the trap, being exposed to the air, putrefied, while the urine in the flask continued clear. To deal, however, more directly with soil-pipe air, the following experiments were performed:—On

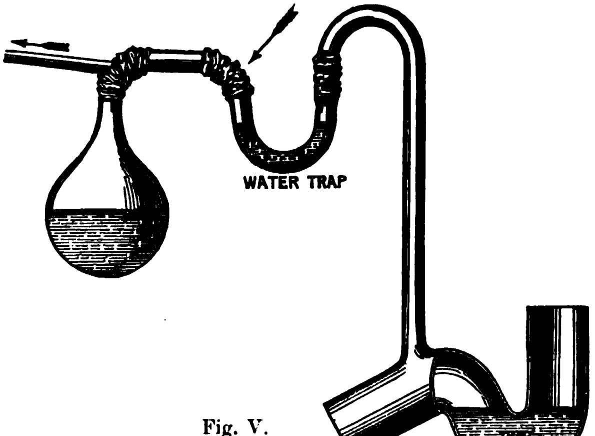

Fig. V.

a shelf across a window, so as to have a good light, a glass flask, having a neck bent so as to form a trap, was placed. (See Fig. V.) Into the flask was put urine; in the trap, water. The neck of the flask was connected to a lead pipe joining the soil-pipe under the trap of the kitchen sink. There was an aperture in the neck of the flask, where this joined the body, for ventilation, and to permit a current of air. The urine in the flask and the water of the trap were sterilized by prolonged boiling. The aperture mentioned was closed with cotton wool while steam issued. The water in the trap, being in direct connection with the soil-pipe air, in sixteen days developed fungi. The urine in the flask has continued unchanged. To-day (18th February, 1880) I examined this urine under the microscope, using a $\frac{1}{12}$ inch Hartnack's immersion lens, multiplying 900 diameters, and found it perfectly free from living organisms. The specimen of this urine, which I now show, you will observe is perfectly clear and transparent, and has no ammoniacal or other putrefactive odour. The experiment was started in July of last year, so that even in seven months germs have not been able to make their way from the soil-pipe, through the little trap of water in the bent neck, into the urine. But, lest it might be objected that there was not a sufficient current of air to draw germs over the curve of the neck, I repeated the experiment with another flask similarly arranged, except that it had two apertures for ventilation in the neck, and that it contained turnip infusion in place of urine. A glass tube, plugged with cotton wool, projected through one aperture into the neck of the flask over the infusion. The infusion and the water were sterilized, and the apertures closed with cotton wool, as before. To the cotton plugged tube projecting through the aperture was now attached the aspirator, which caused a current of air to rush through the cotton wool over the surface of the water of the trap, along to the neck toward the infusion, and out through the small tube. (See Fig. V.) It will be seen from this arrangement, that any particles which might be dispersed from the surface of the water-trap must have been carried in the air current over to the infusion, and must have caused it to putrefy. To-day I examined this infusion as I did the urine, and found it perfectly pure and free from life. The experiment was commenced on September 26th, 1880. The specimen of this liquid which I show you is perfectly clear and free from bad smell, although it has stood for five months. No germs, bacteria, or fungi, have come through the trap even in five months.

Another flask, similar to the first mentioned of these two, containing urine in the body, and having the neck empty, was connected with the soil-pipe. This was sterilized as the others were. In a few days it began to putrefy, and in a few weeks it was very foul and putrid. That in the soil-pipe air which caused putrefaction in this case, was cut off by the water-traps in the other cases. These experiments seemed to me fairly conclusive; but, lest it should be objected that germs might rise from the liquid of the trap and fail to be carried over, or that an ordinary water-closet trap might behave differently from the glass one mentioned, I adopted the following methods of experiment, which I think you will consider crucial. Nitrogen bulbs (Fig. VI.) were charged with Pasteur's solution (one of the best cultivating liquids). The liquid was boiled so as to sterilize it, and while steam was issuing, both ends were sealed in the flame. The bulbs were now wrapped in lint and placed in boiling water for half-an-hour, so as to ensure perfect sterilization of the bulbs. The lead trap in the kitchen, already referred to (see Fig. VI.), was now sterilized by placing under it, and raising so as to immerse the trap, a pot

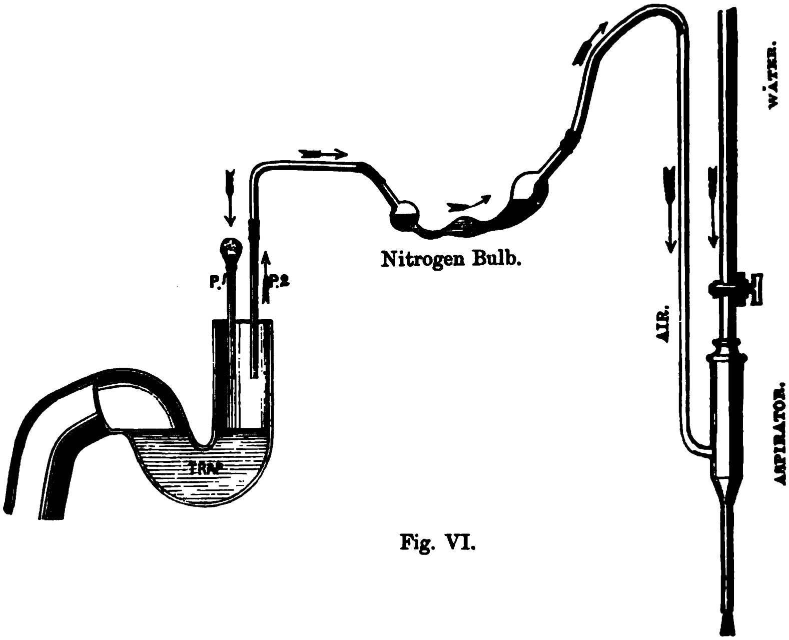

Fig. VI.

of oil heated to from 350° to 400° F. This caused the water in the trap to boil, and steam to flow out abundantly through both tubes. To one of these pipes (P. 2) an india-rubber tube was attached, and, while steam was issuing freely from the other end of this india-rubber tube, one limb of the still closed nitrogen bulb was inserted into and firmly tied in it. The other still closed end of this nitrogen bulb was now inserted into the end of another india-rubber tube (connected to the aspirator), plugged near its extremity with cotton wool which had been soaked in a solution of carbolic acid, and also firmly tied in. Both ends of the nitrogen bulb were now broken off (where they had been previously scratched with a file) within the india-rubber tubes. The aspirator was immediately set to work. The liquid in the bulb was now again boiled by placing a spirit lamp under it. Steam was now coming freely from the open tube (P. 1) entering the cavity over the trap. When this began to slacken, a piece of cotton wool, which had been soaked in an etherial solution of carbolic acid, was tied over the end of this tube, and the whole apparatus allowed to cool. In this way the connection was made, while the whole apparatus was sterilized. The air, entering the cavity over the trap, was filtered by passing through the cotton wool over orifice of tube, passed through this cavity, passed out through the other tube, bearing with it, of course, any particles or gases which might come through the trap, bubbled continuously through the liquid in the bulb, and was discharged through the aspirator. The aspiration was continued for from twenty-four to thirty-six hours. At the expiry of this period the bulbs were, before removal, hermetically sealed by melting near each end, in the blowpipe flame. The bulbs were now removed, and placed in a warm room in a public work, at a temperature of from 75° to 100° F., and were left there for some months. This experiment was frequently repeated, with Pasteur's solution, hay infusion, and urine. Similar experiments were performed with flasks (Fig. VII.), arranged with two tubes passing through carbolized cotton wool in the neck, one tube entering the fluid, the other stopping short of it. Air passing over the surface of the water in the trap was caused similarly to bubble through them. In repeating the experiments with the bulbs and flasks, it was not found necessary to sterilize the trap afresh for each experiment. When the bulb or tube was detached as described, the india-rubber tube connected with the trap remained closed at its free extremity by the hermetically sealed portion of

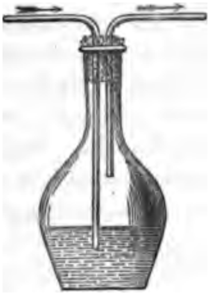

Fig. VII.

glass tube which had been removed from the bulb, remaining in it. This was connected with a fresh bulb, still closed, under a carbolic acid solution, so as to maintain aseptic conditions. In this way experiments sometimes went on for several weeks without the renewal or the fresh sterilization of the water in the trap, which of course must in that time have absorbed a large amount of the impurities of the soil-pipe. The liquids in all those tubes and flasks, though kept for from two to five months at cultivation temperature, have remained perfectly clear, and even when examined with a $\frac{1}{12}$ in. Hartnack's immersion lens, multiplying 900 diameters, exhibited no trace of life. I show you here some of those flasks and bulbs. No. 1 is a flask containing Pasteur's solution, through which the gases which passed through the water-trap were caused to bubble for 36 hours during the 1st and 2nd of January, 1880. The flask has been kept in the cultivating room till to-day. You see that the liquid is perfectly clear and transparent. There has been no putrefaction or development of life. No. 2 is a nitrogen bulb, containing hay infusion, through which the gases over the trap were caused to bubble for 24 hours during 1880, and subjected to the same cultivating conditions. It is equally pure. No. 3 is a bulb containing Pasteur's fluid similarly treated (January 15th, 1880). It is also perfectly clear. Duplicates of these flasks and bulbs microscopically examined to-day show no trace of life. For comparison with these I show you Nos. 4, 5, 6, and 7. No. 4, a flask containing Pasteur's fluid, through which the soil-pipe air drawn from *under* the trap was aspirated (January 14th, 1880), which was placed under similar cultivating conditions. In this you see a very abundant development of fungi, and you perceive that the liquid is foul. No. 5 is a bulb containing Pasteur's fluid, and No. 6 is a bulb containing hay infusion, through which soil-pipe air had been similarly aspirated. Fungi have developed in these very freely, and the liquids are opaque and foul. In some of these, microscopically examined to-day, bacteria and fungi were found in great abundance. No. 7 is a bulb containing Pasteur's fluid, through which I breathed for a few minutes on the 18th of December, 1879. This has developed fungi. These experiments demonstrated the fact that a water-trap cuts off those things in the soil-pipe air which lead to the development of fungi and bacteria. The conditions of these experiments seem to me crucial, and to warrant the conclusion that germs do not pass through a sound water-trap. If no germs pass through, then it is certain that no particles of any kind pass through, because the particles in a soil-pipe are putrid, and because the passage of organic particles through water necessarily impregnates them with germs. Clearly, therefore, such particles as epithelium from the bowels in typhoid fever, containing the typhoid contagium, are cut off and effectually excluded from the house by a sound water-trap. *Water-traps are, therefore, for the purpose for which they are employed—that is, for the exclusion from houses of injurious substances contained in the soil-pipe—perfectly trustworthy. They exclude the soil-pipe atmosphere to such an extent, that what escapes through the water is so little in amount, and so purified by filtration, as to be perfectly harmless; and they exclude entirely all germs and particles, including, without doubt, the specific germs or contagia of disease, which, we have already seen, are, so far as known, distinctly particulate.*

But how comes it that the presence of a water-closet, or of a kitchen sink in a house, produces in many cases such injurious influences on health as has been acknowledged? Clearly, other sources of contamination than the trap must be looked to. Some of these we have already mentioned. As regards the trap itself, there are sources of danger from faulty construction; from misplacement; from accumulation of putrefying filth, in an imperfectly flushed trap; from syphoning or aspirating out of the water in the trap; from pressure in a soil-pipe perfectly tight in all its joints, and perfectly unventilated, causing soil-pipe air to bubble through. None of these dangers, however, belong essentially to the trap; they are all faults separable from an ordinary trap. In the pipe, also, we may find some of the causes which contribute to the contamination of houses with soil-pipe atmosphere. There are found bad joints, cracks, and consequent leakages, perforations on upper surfaces, made by the carbonic acid in the pipe, pointed out by Dr. Fergus, as already mentioned. A pin-point hole in a soil-pipe allows the passage of germs and other particles in considerable quantity, as has been demonstrated by the following experiment, which was frequently repeated:—A piece of lead pipe was attached to the side of the soil-pipe, was flattened to closure at its extremity, and was then perforated with a pin. The end of this pipe was passed through a cotton-wool plug, about an inch, into a flask containing cultivating liquid, which was now sterilized. The flask was now in communication with the soil-pipe only through the pin-hole. After remaining in this position for twenty-four hours, the flask was detached by flattening to closure, or by withdrawing the lead pipe. The fluid could be seen, on shaking, to contain multitudes of motes. Placed in the cultivating room, it speedily putrefied and developed bacteria and fungi. (One of these specimens, No. 8, I now show you.)

A hole, therefore, in the soil-pipe, no larger than might be caused by a pin, is a source of danger vastly more than is a sound water-trap And if the perforations are large, we can readily understand how, especially when fires are actively burning in the house, large quantities of soil-pipe atmosphere, with its particles, may be drawn into and contaminate the house. Such a source of danger is a serious and, unfortunately, a not very uncommon one. This source of danger is now, however, well known to all acquainted with our drainage system. The dangers arising from the construction of the pan water-closet itself are, however, by no means so well appreciated. In the trunk of the closet (Fig. I.), in the pipe between this and the trap, and in the safe pan or tray on the floor under the trunk, are constant sources of escape of the products of putrefaction, and of consequent injury to health. The tray is designed to catch any overflow that may take place from the basin of the closet, or any leakage through the trunk. This it conducts to the trap of the soil-pipe with which it is connected. Being only occasionally moistened, it is never clean. It almost invariably contains a mass of slimy, putrid filth, covered over most of its surface with fungoid growths. This filth is in the condition to discharge and disperse its foul particles. It constantly gives out a sickly fœtid odour, and is, in fact, an important cause of that disagreeable smell so frequently noticed in otherwise clean closets. The trunk of the closet is, however, a source of more danger than even this tray. Dr. Ford, of Philadelphia, in Buck's *Hygiene*,* says that "water and fæcal matter are thrown against the sides of the receiver, which soon become coated with a mass of foul matter. This undergoes decomposition, and the noisome gases generated collect in the receiver between the two traps, and are thence discharged into the apartment and through the house at every use of the water-closet." Mr. P. Hinks Bird, in *Hints on Drains, Traps, Closets, and Sewer Gas*,† says, "It is to be regretted that among the hundreds of patented inventions lately brought before the public, one of the most defective and dangerous of them should have got into such general use—the ordinary 'pan closet.'" Mr. Baldwin Latham, writing of this closet,‡ says "they are expensive and cumbrous appliances, and cannot be introduced within a house without creating a nuisance." "The fæcal matter and water are thrown against the receiver," which "gets completely coated with fæcal matter—so much so, that it is the practice in many establishments to have the deposit burnt out; but this cannot remedy, but only palliate the nuisance, as the continual plastering of the interior walls of the receiver with fæcal matter in the presence of moisture causes decomposition to take place, and noisome gases are generated, which accumulate in the receiver between the two traps; and every fresh discharge from the closet displaces an amount of this foul vapour which passes at once through the open basin into the apartment, and thence into the house, and no amount of ventilation of the receiver will remedy this defect, which is inherent to this particular form of closet." If you examine such a trunk as is found in almost every house in Glasgow, you will find it thickly coated over, to the thickness, frequently, of an inch or more with filth. This always emits a fœtid or a positively stinking odour, and in this respect contrasts strongly with the new (Fig. III.) trap with which I experimented, which never gave out any decidedly bad smell. In experimenting with a trunk, removed from a house in Abbotsford Place, by closing it at top and bottom, and aspirating through it, I found the amount of gases given off decidedly more than came through the trap. The quantity of gases was, however, too small to do any injury, but unlike the gases coming through the trap, they come off plus putrid organic particles. Under ordinary circumstances this is a nuisance, but only to a slight extent a source of injury to health—still it is a much greater source of injury than is the water-trap. But suppose that into such a trunk are thrown the discharges of a patient suffering from typhoid fever, the fever contagium, imperfectly or not at all disinfected, putrefies and becomes a very positive source of danger to all using the closet, and perhaps to the whole house. This may perhaps account for the recurrence of typhoid in a house, in many cases. I do not wish to magnify this source of danger. It is probably not a very serious cause of injury; still it is decidedly worthy of consideration, and it at once suggests the question, Can we not have closets free from this danger? Are there no water-closets less complicated, and without filth-retaining cavities? There certainly are, and many forms of them. One of the best of these in use at present is the Jennings water-closet. This is composed of one piece of glazed earthenware, the upper portion of which forms a large shallow basin, in which a little water lies, and which communicates by an opening in the back or side with the lower portion, which forms a trap immediately under the basin. There are many modifications of this form in use, an excellent one of which may be seen at the Central Station in Gordon Street, Glasgow. Closets made in this pattern are greatly superior to the pan closet. They have no closed cavity containing foul air and lined with filth; they are entirely above the floor, and they are little liable to get out of order. Something more simple, however, it seems to me, will answer the purpose much better. What we have to aim at are the speedy removal out of the house of excreta; the exclusion of the injurious substances contained in the soil-pipe; and perfect cleanness of all parts of the closet itself. A simple trap excludes all injurious substances which the soil-pipe may contain; the simplest method of getting the excreta passed through the trap is a good flush of water; and perfect cleanness of the closet and trap may be secured by having the inside of the trap at its deepest part exposed to sight. A basin with its outlet so curved as to form a syphon trap, the deepest part of which is seen from the basin, the whole formed of one piece of glazed earthenware, fulfils all the conditions of a simple, clean, safe, and cheap water-closet. (Fig. VIII.) It should have

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* *A Treatise on Hygiene and Public Health*, by Albert H. Buck, M.D., 1879, vol. i., p. 503.

† Blackpool, 1877, p. 39.

‡ *Sanitary Engineering*, p. 506.

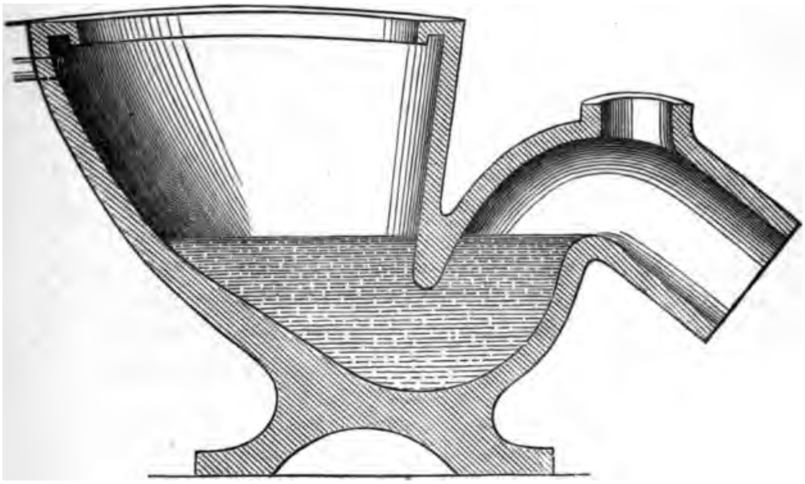

Fig. VIII.

on joinings, into which urine may soak and decompose; it should be perfectly smooth, so that fæces do not readily adhere; the deepest part of the trap should be perfectly in sight; the back of the basin, instead of curving forward, as is usual with closets, causing this part to be very frequently soiled with fæces, should curve back; the front part also should slope back, so that the centre of the surface of water may be under a point in the antero-posterior diameter of the seat, about two-thirds from the front, so as to cause the fæces to drop directly into the water—not on the back of the basin; the seat of the closet should be lower than the present form, as most people find the present seat too high—indeed, it should be about the height of the seat of an easy chair, say about 15 inches from the floor; it should have a flush of water, in the form of a full jet striking the surface of the water directly in the curve of the outflow, with a wave or fine spray washing the sides of the basin. I do not assert that any one of these conditions is entirely new, but, so far as I am aware, no closet has ever been in use which conforms to all the conditions I have laid down. That such a closet will work satisfactorily is certain, because I have had in use for two months one fitted up so as to conform to most of the conditions laid down. This closet works easily, keeps perfectly clean, and is perfectly free from any smell. It requires about one and a half gallons of water to flush it and clear out the excreta, so that it works well with less than the two gallons of water allowed by the Water Commissioners of the city. This water-closet, I believe, could be made to sell at from 15s. to 18s. (perhaps less) complete. It would, therefore, be much cheaper than the present closet in its first cost, and it would be very much less liable to get out of order, as there are no joints or cranks about it. It cannot choke; it consequently is very much cheaper to keep in repair. Such a closet can be, and ought to be, kept as clean as a wash-hand basin. A specimen of water which has stood in this closet for 72 hours, I now show you. It is perfectly clear and free from smell. On analysis it showed—

	Grains per Gallon.	
Free Ammonia, ...	$\frac{1}{50}$	$\left.\right\} = \frac{1}{28}$
Albumenoid Ammonia, . . .	$\frac{1}{70}$	
Sulphuretted Hydrogen, . . .	$\frac{1}{5}$	
Carbonic Acid, ...	14	

This shows how little ordinary soil-pipe air will contaminate the water in a *clean* trap.

The principle just laid down concerning the water-closet trap might be applied to all traps within a house—*i.e.*, they should be so arranged that they can be seen into to their deepest parts. A wash-hand basin could easily be shaped so as to have its trap constitute a portion of the basin, and to be in its deepest portion in sight. So with sinks and baths. On these points I simply throw out the suggestion, asking you to bear in mind that what is wanted in each case is a sound water-trap so arranged that it may be kept perfectly clean. The water-closet apartment should never be situated in the centre of a building, but should, if possible, be in a separate brick shaft, shut off from the house and ventilated freely. The junction of the closet with the lead portion of the soil-pipe should be made perfectly secure, and as this is the only junction that should exist in the house, it can be made certain. This pipe should pass as directly as possible out of the house, and should join the iron soil-pipe outside, not in the wall. The soil-pipe should discharge into a ventilated trap, and should be carried full bore above the house, so as to be perfectly ventilated by a constant current of fresh air. The kitchen sink should discharge under an open grating or into the rain water pipe, which should be ventilated well at top and bottom. The effect of ventilation on soil-pipe atmosphere has already been noticed. The principles, then, which ought to govern the regulation of house drainage are mainly as follows:—

1. All filth and all organic waste matter which are liable to putrefy should be immediately and completely removed from the inside of the house.

2. All pipes (water-closet, bath, sink, or other) discharging such matters should, as far as at all possible, pass directly from the house apparatus to the outside of the house. Drains should not, if it can be avoided, pass under a house.

3. A water-trap to close the house end of every such pipe should be so arranged as to be thoroughly open to view to its deepest part, that it may insist on being kept clean.

4. There should intervene between the trap and the house no cavity or surface, in or on which foul air or filth can accumulate.

5. All discharge pipes, inside or out of the house, should be well ventilated by openings at top and bottom. In the case of pipes passing through the house for any great distance this is imperatively called for.

If these principles are carried out efficiently, they will render it possible to maintain perfect cleanness in the house as regards the discharge of organic waste substances, and perfect immunity, I venture to assert, from any injurious effect on health from this indirect connection with the sewers.

Discussion.

The Chairman said—I must say that I feel personally, as I am sure we all feel, very deeply indebted to Dr. Carmichael for the very admirable paper he has read, and, really, that paper conveys but a very faint and very inadequate idea of the amount of labour that he has bestowed on the subject. I was greatly struck and interested with the experiments Dr. Carmichael made formerly, and which he read to the Society; and with that in view, I spoke to him on this subject, and he has taken it up. But you can have no conception of the minuteness of detail and the delicacy of handling that such a subject requires. I had an opportunity of going over and seeing what Dr. Carmichael had done, and found to my very great surprise—in fact, I have not yet been able to solve the mystery—of how a man so busy as he is can have devoted so much time to this subject. I know no one whose experiments are more trustworthy, or who bestows more care and attention on the conduct of these experiments; and I know, and am quite certain, that the half of the subject has not been told yet. I beg to propose that we accord him a cordial vote of thanks. (Applause.)

Dr. JAMES MORTON said he felt considerable diffidence in the presence of so many men learned on the subject, in rising to say a few words, but he trusted he was only breaking the ice, and that several of those gentlemen would speak afterwards. He sympathised so strongly with the remarks made by the Chairman, that he could not resist the temptation to say how much gratified he was with the paper of Dr. Carmichael. The feature in it which gratified him most, and which must have commended itself to the members of the Philosophical Society, was the extreme reluctance of Dr. Carmichael to draw any general conclusions. An amount of caution, which might be called scientific caution, was manifested by Dr. Carmichael, which was entirely creditable to him in every respect, and was particularly commendable in a young man. Some men were apt to be sanguine; Dr. Carmichael was serious, and had treated the subject in an exceedingly able manner.

Dr. WILLIAM WALLACE, City Analyst—We are very much obliged to Dr. Carmichael, because he has not brought before us any theory or haphazard statements, but statements of actual facts. These facts are of very great value. Some of us have had opinions which these experiments made by Dr. Carmichael bear upon, favourable to his views and the results of his experiments, and some otherwise. But it is of very little value indeed to hazard opinions when it is possible to make experiments, and Dr. Carmichael has taken the true way to arrive at the proper conclusion. All the experiments he has made are very accurate, and he has carried them out with great minuteness, and I have no doubt they have occupied him for a very great length of time. I have to add my testimony to the great value of Dr. Carmichael's paper.

Mr. BUCHAN—I beg to express, on my own behalf, the great debt we are under to Dr. Carmichael for the immense labour he has bestowed on his researches into this very important subject regarding the health of the community. It is a subject on which various men have been divided in opinion for many years. I have taken part in the battle, and, I am happy to say, the side that I fought upon was the side which Dr. Carmichael has so well shown to be the right side. He has supported the value of one appliance which plumbers must use to protect the inmates of a house from the effects of the gases and disease-breeders which are in the drains and sewers. A great many medical gentlemen and engineers, and plumbers too, I find have been stating that the trap was a nuisance, that it should be done away with, and that there should be simply water in the pan, and so houses would be far safer without the trap than with it. I have taken the liberty on many occasions to say that that idea was absurd. Where you have a ball valve in place of a simple water-trap, it may very often happen that a bit of paper will stick to the ball or end of the pipe, and you have thus air blowing over a large surface from the drain or sewer into the house. In many cases where the medical adviser of a family has found disease, it has been found to come from defects in the apparatus. And, so far as I can remember, I have never found any medical practitioner, not even Dr. Fergus himself, say in my presence that disease had ever occurred in a family, or anywhere, from gases after they had passed through the water-trap. So far as I remember any case where disease was caused, it arose from defective joints, holes in the pipes, or sewer gases from the drain—gas getting into the house in some way, but not from water in the trap carrying disease-breeders into the house. If air with any germs in it was flowing into the apartments, these germs would attach themselves to the apparel in the apartments, or the paper in the rooms, or the furniture, or anything else, and would gradually accumulate; and that is one of the reasons why, even if the hole may not be very large in the soil-pipe, it will affect the room in the course of time, and be a source of deterioration to health even where there are no actual disease-breeders in the case. I think the Society is very much indebted to Dr. Carmichael for the experiments which we have heard explained to-night.

Mr. W. R. W. SMITH—I have been very greatly gratified by the experiments which Dr. Carmichael has brought before us, but there is one little matter in reference to these soil gases that has always struck me, which those gentlemen making experiments have never taken into consideration, and I would desire to direct Dr. Carmichael's attention to it. He showed us certain vessels containing urine which had been exposed to sewer air. I wish to ask if he considered the conditions of the barometer at the time he was noticing the passage of that air? I have not any definite experiments on the subject, but I have made a series of observations, and those have invariably led me to this idea—that it depends upon the condition of the atmosphere whether there is a heavy current of sewer gas, or perhaps a current down the sewer pipe, although in some instances there is air produced, to a large extent, by passing through the pipe. That is a point which I think Dr. Carmichael, with the minutiæ which he has shown in his experiments, might do well to take into consideration.

Mr. Bromhead—After such a very carefully prepared and excellent scientific paper, it seems to me a pity that we should be taken aside from the real point. It seems to me that some of the speakers have very much misunderstood the lecturer, if it is supposed that he demonstrated that the apparatus which plumbers are now putting up are satisfactory. It seems to me that the whole moral of this very excellent address is that the water that has been used, perhaps in the machines that plumbers have been putting up, has been satisfactory to a certain extent; but I certainly understood the whole gist of the paper to mean that the apparatus that plumbers have put up to hold that water, to make them useful, have all to be cleansed to carry out the object for which they are intended. I would also ask that, in the printing of this paper, the illustrations which Dr. Carmichael has shown may be put into the book.

Dr. Carmichael, in replying, said—I thank you very much for the way in which you have received this paper. I can assure you it is only a very small portion of the work which I have brought before you. You have been kind enough to overlook certain imperfections in getting up the paper, which were inseparable from the attempt to condense what I had to say. Mr. Buchan was perfectly right in saying that the little valve at the top of the new closet outflow pipe was meant to ventilate that portion of the pipe. As to the remarks of Mr. Smith about the barometric pressure, I have only to say that I continued these experiments of mine regularly for from five to six months under all the varying conditions of atmospheric pressure. I think that eliminated the difficulty very thoroughly, and I have not yet entered into any particular effect of barometric pressure by way of experiment, because the fact is that experiments performed, as I have shown you, under whatever barometric pressure, gave invariably the same results. Mr. Bromhead has spoken of the structure of the traps. What I wish to demonstrate is that even such traps as those old ones exclude the foul gas. The details, as they are at present arranged between the trap and the house, invariably admit of a portion of foul or dirty pipe, and that I want to have removed by having all the traps in sight.

The vote of thanks having been passed to Dr. Carmichael, the proceedings terminated.

XI.—*On Provident Dispensaries as a Means for promoting the Public Health.* By JAMES CHRISTIE, A.M., M.D., Lecturer on Hygiene and Public Health, Anderson's College, Glasgow.

[Read before the Society, March 3rd, 1880.]

THE establishment of Provident Dispensaries in the metropolis and provinces has, during recent years, excited much attention among social reformers; and the efforts put forth in this direction have been, if not eminently successful, hopeful, to say the least of them.

Public attention was first called to this subject about twelve years ago, chiefly in consequence of the gross abuse of the metropolitan medical charities; and the first combined effort to remedy the existing evils was made exactly ten years ago, in March, 1870. At a meeting, presided over by the late Sir William Fergusson, at which 156 members of the medical profession were present, the following resolutions were passed:—

"That this meeting is of opinion that there exists a great and increasing abuse of outdoor relief at the various hospitals and dispensaries of the metropolis which urgently requires a remedy;" and

"That, in the opinion of this meeting, the evils inseparable from the system of gratuitous medical relief administered at the outdoor department of hospitals, and in free dispensaries, can be in great measure met by the establishment, on a large scale, of Provident Dispensaries, not only in the metropolis, but throughout the kingdom, and by improved administration of Poor Law medical relief."

A large committee was then appointed, which apportioned the subject among four strong sub-committees on "General Hospitals," "Special Hospitals," "Dispensaries," and "Poor Law Medical Relief," of which Dr. Meadows, Dr. J. E. Pollock, Dr. Stewart, and Mr. Spencer Wells were respectively chairmen, all of them men of the highest professional standing in the metropolis.

In evidence of the great and increasing abuse of outdoor relief at the various metropolitan hospitals and dispensaries, I may quote the following from an article in the *British and Foreign Medico-Chirurgical Review* of January, 1875, on "The Limits of Unpaid Service."

"The reports of the several medical charities—free hospitals and dispensaries—show how enormous is the number of persons who annually seek advice and medicine from these institutions. Several writers have computed what is the total number of individuals who annually apply to the medical charities of the metropolis, and they tell us that it is over a million. We have ourselves gone carefully through the figures for the year 1873, and we make the total 1,288,085. This is altogether exclusive of the poor law, and of a great number of private and semi-private institutions which publish no reports. Beyond the medical charity which can be estimated in figures, there is a large amount which cannot be tabulated. We may, therefore, rest assured that the total at which we arrive by adding together the figures given in the various published reports is not an exaggerated one; but that, on the contrary, it represents only a proportion—a very large proportion, no doubt, but still only a proportion—of the whole charity of the metropolis. And what is true of London is true also, though in a less degree, of the provincial towns of the country at large.[1] We may, therefore, safely conclude that a very large percentage of the community rely upon medical charity in time of sickness. In the metropolis this proportion amounts to something like a quarter."

The writer goes on to remark that—

"This, then, is the first fact to which we call attention—the enormous number of persons who expect to receive their medical attendance and medicine at the expense of their neighbours, as a matter of charity. It needs no argument of ours to prove that this is a very undue number. In exceptional circumstances—for example, when famine devastates a country—a great part of the population may have to rely upon charity in one shape or another for the necessaries of life. But if such a state of things became chronic, we should think that it augured very ill for the prosperity of the people. Soup kitchens are excellent institutions on an emergency, but it would not be beneficial to have them always in operation, for the supply of all comers. And the principle is the same with regard to medical charity. Sickness is not one of the necessities of life, and yet it may truly be said to be one of its necessary accidents. It is a contingent event, but a contingent event which, speaking generally, is certain to come sooner or later. Is it wise then, to rest contented with a state of things which permits so large a proportion of the population to rely upon the charitable help they can obtain from others in a matter which is, sooner or later, a practical certainty—almost as much a certainty as that another meal will be needed, or another suit of clothes? It seems to us that no thoughtful person can acquiesce in a state of things which, under the name of charity, is in truth pauperising a large section of the community, and inducing them to depend, not upon their own prudence and forethought, but upon the aid they can derive from others."

That the most flagrant abuses existed, and were increasing to an alarming extent, was evident; and it was found that a pressure was brought upon the hospitals greater than they were able to bear. According to Dr. Meadows, "the poor were being gradually ousted out of the consulting room by well-to-do persons; and he knew, as a fact, that persons in the possession of incomes of £1,000 a year came as out-patients to receive advice, and that the wives and daughters of men almost as wealthy actually borrowed their servants' clothes in order to apply as outdoor patients."

So great had this evil become that, according to parties who had investigated the matter, in the interior of London, including its great eastern and southern quarters, nearly all below the middle class, and some even of them, were provided with medical attendance and medicines by private charity, with some assistance from the Poor Law. As a matter of course, medical relief of this kind was little better than a mockery, owing to the impossibility of giving sufficient time and attention to each case. The waiting rooms of the hospitals and free dispensaries were besieged by crowds of patients, who were frequently seen, and passed through the medical and surgical mill at the rate of fifty per hour.

Those who thus depended upon the outdoor patient department of the hospitals for their medical relief, after wasting perhaps a day in begging for a subscriber's letter, and half-a-day in the waiting room of the hospital, got on an average, perhaps a minute of the physician's or surgeon's time, one whom they had never seen before, and might never see again; and perhaps, in addition, a bottle of medicine, for which they would require to wait an hour or two, and which, most likely, they never took. The whole affair became necessarily a pious, or rather a charitable, fraud—a fraud on both contributors and patients, medical officers and students.

While the leading medical men of London, and specially those whose names are familiar to us in connection with the hospitals, were moving in the matter of hospital reform, the *Charity Organization Society*, having for its object the improvement of the permanent condition of the poor, came to the conclusion that one of the most powerful of the causes by which their condition had been depressed was this system of gratuitous, indiscriminate medical relief; and that every other arrangement for their benefit must fail in producing its full effect while this evil remained unremedied. The Council of the Society, therefore, appointed a committee to investigate the matter, and, in October, 1871, this committee made a report, pointing to "a large development of the provident principle" as the appropriate remedy for the abuses of the medical charities; and submitting model rules for the management of Provident Dispensaries, based upon the experience of those institutions.

The *Charity Organization Society* have held three conferences on the subject: one in 1871, which was attended by Mr. W. H. Smith, M.P., and by Mr. Stansfeld, M.P.; the second under the presidency of Dr. Acland, the president of the General Medical Council; and the third under Lord Frederick Cavendish.

In 1875 a large and influential section of the medical profession, resident chiefly in London, moved in regard to the question of hospital and free dispensary abuse as inflicting a serious injury upon many deserving members of the medical profession; and a petition was presented to the president and committee of council of the British Medical Association, to take into consideration the relation of the medical profession to the hospitals and free dispensaries throughout the kingdom. When called upon by the committee "to devise some measure of reform," it was proposed, *inter alia*, that at all hospitals and free dispensaries there should be some system whereby on effectual inquiry might be made into the social condition of the applicants for medical charity, and their ability or non-ability to pay something for themselves; and that, in the development of the "Provident System," and the various modifications of which it is susceptible, a remedy might perhaps be found for the evils which have become apparent.

A committee of the Association on "Hospital Outdoor Patient Reform" was accordingly appointed; and, since that time, it has been a standing committee which reports annually to the Association, a sub-committee having been also appointed on "The Working of the Provident System."

At the last conference of the Charity Organization Society, the president, Lord Frederick Cavendish, said, in the course of his address on this subject:—"You had best go to the Friendly Societies, for they are acquainted with the principle of association, and the principle of self-help." The advice of Lord Cavendish was acted upon, and in the year 1878 circulars were sent out to the Friendly Societies, containing a proposal to form a Metropolitan Medical Association. The answers received being not only favourable, but of the most encouraging nature, a new point of departure was taken, as it was seen that the provident scheme, on a large scale, could be better carried out by an independent agency than by committees of the Medical Profession, or of the Charity Organization Society.

In June, 1879, a large representative meeting was accordingly held in London, under the presidency of the Right Hon. James Stansfeld, M.P., to consider the proposal placed before the representative working men of the metropolis by the medical committee of the Charity Organization Society, to form a "Metropolitan Medical Association," whereby members of the working-classes and their families might be insured in health for medical attendance and medicines in sickness and disease. The conference had been called by gentlemen representing, in the first place, the Charity Organization Society; secondly, by the representatives of the Hospital Saturday Fund; thirdly, by the associations of working-men—those great Friendly Societies of the metropolis—and provident dispensaries; and by gentlemen connected with the great hospitals of London. At this meeting two resolutions were adopted, the first being in favour of the establishment of a metropolitan association for the purpose of providing for the ordinary medical treatment of the industrial classes on provident principles, in due relation to the hospitals; the second being that a representative committee be appointed to prepare rules, to be submitted to a subsequent meeting. The committee was constituted as follows:—*Chairman.*—The Right Hon. James Stansfeld, M.P. *Members of the Charity Organization Society.*—Sir Charles Trevelyan, Bart., K.C.B., Mr. W. Bousfield, and Mr. J. R. Holland. *Members of* *the Governing Bodies of Hospitals.*—Sir Thomas Fowell Buxton, Bart., Sir Rutherford Alcock, K.C.B., Mr. E. H. Lushington. *Members of the Medical Profession in the Metropolis.*—Mr. Timothy Holmes, Mr. Ernest Hart, Dr. Joseph Rodgers. *Representatives of the Saturday Hospital Fund.*—Messrs. Mackenzie, Byne, and Frewer. *Members of the Ancient Order of Foresters, of the Independent Order of Oddfellows, of the United Patriots' National Benefit Society, and of the Druids.*—Messrs. Radley, Cripps, Herne, Newman, Armstrong, and Witted. At the first meeting of this committee, in July last, a sub-committee was appointed to prepare the first draft of the scheme; and it was resolved that the scheme be based on the following principles:—1. That, as the dispensaries are intended to be for that portion of the population which is between the class able to pay the usual professional fees and the destitute class provided for by the Poor Law, the rates of payment and the expenses should be arranged in accordance with that view. 2. That the rates of payment at the dispensaries be sufficient to defray the current expenses, including the due remuneration of the medical officers. 3. That the best mode of providing for the preliminary expenses and outfit be specially considered by the subcommittee. 4. That a carefully considered arrangement be prepared for the prompt interchange of cases among dispensaries and hospitals according to their respective requirements. 5. That an arrangement be also made to secure skilled and experienced nursing for dispensary patients when necessary.

In this brief sketch which I have given of the movement for the establishment of Provident Dispensaries in the metropolis, you would observe that it had its origin almost simultaneously in the ascertained abuse of the metropolitan medical charities, and in facts brought to light through the investigations of the Charity Organization Society.

The committee appointed at the meeting presided over by Sir William Fergusson, the Medical Committee of the Charity Organization Society, and the Memorialists to the British Medical Association, all agreed on one point—viz., the establishment and extension of Provident Dispensaries as a mode of getting out of the difficulties of medical charity abuse, and of successfully grappling with mendicity. Provident Dispensaries have been in existence, in various parts of the country, for nearly half a century; and their results have been so far satisfactory, that those interested in the reforms indicated could point to existing institutions as being thoroughly adapted to the wants of a large and important section of the community.

But although the movement had its origin in the recognition of certain abuses, and was intended to rectify existing evils, the system of Provident Dispensaries is now being discussed on its own merits, and should be considered as a question of Social Science, in the department of Public Health. This aspect of the question was well illustrated by Mr. Timothy Holmes in some remarks which he made at the meeting in London, in June last:—"As a faithful servant of the hospital system of London," he said, "there was a most important function connected with the medical relief of the poor to which very little attention was paid. The mere treatment of disease was but a fraction as compared with the importance of preventing disease. The hospitals could do little in undertaking this function, and any institution, to do this, must treat disease in the homes of the people; for it was in the homes that the great epidemics were nursed, and it was only in the homes that many complaints could be treated, and that the medical man could give advice as to the manner of living. A medical man must know how a man lived before he could treat a case, and in seeing a man for a minute in the out-patient department of a hospital, and giving him a bottle of medicine, no assistance was given to help the general standard of health. The hospitals performed great functions; but this out-patient system, as now carried on, did not permit of the standard of health being raised."

Sir William Gull looks at the Provident Dispensary movement from the same standpoint. In the discussion, in which he took part, upon Sir Charles Trevelyan's paper, in 1877, he said:—

"If provident dispensaries were more generally established, and the medical men attached to them were constantly to visit, at their own homes, the patients who were too ill to personally attend, the best influences would be brought to bear upon this class of society. Most of you know that the poor have an idea that disease comes from Providence, and that it must be cured by drugs. Now, if there is any idea that ought to be rooted out, it is this. Children are often brought to be drugged, when, in reality, they require to be washed and fed. I believe that one of the beneficial effects of our meeting will be, that it will have a tendency to spread abroad the fact that disease should be prevented by attending to hygienic laws, by eating good food, which has been properly cooked, by regulating the quantity and guaranteeing the quality of that which is taken. The existence of gin palaces at one corner of the street, and free dispensaries at the other, are evidences, by contrast, of the monstrous anomalies existing in our society."

It is fortunate, for the success of the movement, that the Provident Dispensary Scheme is now placed before the public, not for the purpose of solving the questions of charity abuse, of mendicity, of the invasion of professional interests, &c., &c., but to determine the question as to how the health of the working-classes, who are the backbone and the basis upon which the prosperity of the country must rest, can be best secured? It is not a "doctor's" question, though medical men have to do with it; it is a social economy question; for, as Dr. Rumsey has well said, "Many of the social burdens arising from widowhood, orphanage, and funeral expenses, which have been attributed to defective sanitary arrangements, depend also, in great measure, on the want of early care and attention at the hands of duly qualified medical practitioners. An immense amount of productive labour is lost to society by mortality which might be diminished; and by sickness, which might be either prevented or curtailed."

Before discussing the question as to whether the Provident Dispensary Scheme is applicable to such a city as Glasgow, it may facilitate a clearer conception of the scheme were I to read to you extracts from the "Model Rules for Provident Dispensaries," issued by the Medical Committee of the Charity Organization Society, in June, 1878, as I am not aware that the Committee of the Metropolitan Association, appointed in June, 1879, have yet issued their rules.*

I. *Object.*—The object of the Institution is to secure, on provident and mutual assurance principles, medical advice and medicine, during illness, for the working-classes, domestic servants, and other persons who are unable to pay the usual professional fees. The benefits of the Institution are intended for persons living within the district bounded by————, but may be extended to others outside, at the discretion of the Committee, and with consent of the medical officer who has to attend.

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* The Provisional Committee for the establishment of a Metropolitan Association have, since the above was written, issued their scheme, which is a very valuable document. The Committee recommend that the new system should be, from the beginning, free from the taint of dependence and pauperism, believing that "a subsidy of any kind would be a mistake, as tending to destroy self-respect and independence."

II. *Constitution.*—The members consist of two classes—"Honorary" and "Provident." Subscribers of one guinea are honorary members; and donors of not less than five guineas, and ministers of religion, and others, who collect ten guineas or upwards, are honorary members for life. The provident members are those who make the prescribed payments, and are thus entitled to receive the aid of the Institution. Persons whose average gains do not exceed forty shillings a week are eligible for membership, unless the average earnings of a father, and his children under sixteen, amount to more than forty shillings a week, in which case they are ineligible except under special circumstances. Every adult member of six months' standing, whose subscription is not in arrear, may vote at the general meetings, and is eligible to serve on the Managing Committee.

III. *Committee of Management.*—The immediate direction and management of the Institution is vested in a committee consisting of the president, treasurer, medical officers, and ——— members elected at the annual meeting, of whom one-half may be provident members. *(Here follow powers of the Committee.)*

IV. *General Meetings.—(Here follow regulations as to such.)*

V. *Provident Members.*—Provident members will, in right of their payments, be entitled to all the benefits of the Institution, including medicine as well as medical advice, and attendance at their own homes when needed. The days of attendance of the several medical officers at the dispensary will be made known. Members will name the medical officer by whom they wish to be attended, but no change can take place during illness without the consent of the committee of management. Any person who wishes to become a member must give his or her name, age, residence, and occupation, with the like particulars as to wife and children, if any, and such information as may be required as to the circumstances of himself and family; and must deposit one month's subscription, which will be returned, if the application is declined.

The scale of monthly payments is—

Each person above 16, ...	8d.
Man and wife, ...	10d.
For each child (up to three), . . .	2d.
Widows, ...	4d.
For each child of a widow (up to three), .	1d.

all of which must be paid in advance.

Children can only join with one of their parents or guardians. Not more than three children will be charged for in any one family. All others will be free. *(Here follow rules as to payments in advance, and arrears.)* Applicants for membership actually suffering from illness, requiring medical treatment, must pay six months in advance. Patients who are able must attend at the dispensary at the appointed times, bringing their member's cards with them. Patients too ill to attend at the dispensary must send their cards, before ten o'clock in the morning, to the residence of the medical officer they have chosen, who will see them at their homes. In cases of sudden illness or accident, members will be attended at any time on sending their cards to any one of the medical officers. Married women, having been members for three months, may be attended in their confinements by one of the medical officers upon payment of 15s., or by one of the midwives upon payment of 7s. 6d. These payments may be made in one sum, or by instalments of not less than 2s. 6d. each, and must be completed one month before confinement. The midwives will, in cases of danger or difficulty, call for the assistance of one of the medical officers skilled in midwifery. The children of members will be vaccinated without charge.

VI. *Medical Officers.*—The medical officers will be elected by the committee of management from persons qualified to practice under the Medical Registration Act, at least seven days' previous notice of vacancies being given by public advertisement. The medical officers will attend at the dispensary on such days and hours as the managing committee deem requisite, and will visit patients at their own homes whenever the case requires it. They shall each keep a register, according to a prescribed form, of all cases treated by them, and report quarterly to the committee on the statistics of health of the members under their care. One-half of the payments of the provident members (with the exception of the midwifery fees) will be divided at the end of every quarter or half year among the medical officers, in proportion to the amounts received from members registered under their names. The midwifery fees payable to the medical officers will be made up to one pound for each case out of the dispensary fund. The balance of members' payments, together with the contributions of honorary members, will be appropriated towards the expenses of management. The committee will distribute at least two-thirds of it among the medical officers. Assistants shall not be employed without the permission of the committee.

VII. *The Midwives.*—The midwives will attend to lying-in cases under the directions of the medical officers, and shall send for a medical officer in any difficult or unusual case. They will continue their attendance for fourteen days after delivery. They will be paid the member's lying-in fee of 7s. 6d., and 2s. 6d. from the dispensary fund.

VIII. *(Refers to Dentist.)*

IX. *Nurses.*—The committee will, by arrangement with a Nursing Association, or in some other way, endeavour to obtain the advantage of skilful and tender nursing in sickness for those members who are reported by the medical officer to require this assistance.

X. *Recommendation of Cases for Consultation or Treatment at Hospitals.*—When a patient can be more satisfactorily dealt with at a general or special hospital, it will be the duty of the medical officer in charge of the case to recommend it accordingly, either for consultation or treatment, as the circumstances may require; and, if requisite, he will himself join in the consultation.

XI. *Reciprocal Benefits between Provident Dispensaries.*—Members leaving the district will be entitled to a certificate of all arrears having been paid, with a view to their being admitted at once to other Provident Dispensaries upon the usual payment of one month's subscription in advance; and they will be readmitted on the same terms in the event of their returning to their original district.

Having placed before you the general scheme of Provident Dispensaries, I proceed to the question, Is there any necessity for the institution of such dispensaries in the city of Glasgow and in similar large centres of industrial populations? I, of course, answer the question in the affirmative.

I find, from Dr. Russell's Report upon "Uncertified deaths in Glasgow," published in 1876, that, in 1874 there were 38,910 patients treated in connection with the four Medical Charities in Glasgow—viz., the Royal Infirmary, the Western Infirmary, the Maternity or Lying-in Hospital, and the Medical Mission—representing one-thirteenth of the entire population. Of these, 1,556 were treated at home and supplied with medicines by the medical officers of the Medical Mission; 29,409 were treated in the Public Dispensaries; and 6,654 within the two hospitals. The confinements in the houses of patients numbered 986, and in the Maternity Lying-in Hospital, 305. The total number treated by private charity, omitting midwifery cases, was 72 per 1,000 of population, as compared with 200 in Edinburgh, and 236 in Liverpool. Since that period the operations of the Glasgow Medical Mission have been extended, and the public dispensary at Anderson's College has been opened, the latter also supplying medicines gratis. In this enumeration I have not taken into account the special hospitals and dispensaries for diseases of the eye, ear, and throat. I need scarcely mention that the public dispensaries are free to all comers, without "lines" from subscribers; but that, for admission to the hospitals, subscribers' "lines" are necessary. For the London dispensaries, governors' letters seem to be necessary, and medicines are given; whereas, in Glasgow, medicines are only given in exceptional cases, and the dispensaries are open to all, without questions being put as to the circumstances of the patient. Although 39,000 patients treated, in part at least, by private charity looks a large number, I do not think that the private charities of this city are abused, or taken advantage of by the public to any great extent for the purpose of avoiding payment for what they are able to pay. Speaking from my own experience as one of the dispensary surgeons of the Western Infirmary, I have much pleasure in stating that that medical charity is not abused, but that, on the contrary, it is taken advantage of by the very class for whom it is intended; and I believe that the dispensary surgeons of the Royal Infirmary can bear testimony to the same effect. A large number of the cases require minor operations, and subsequent dressings; while a considerable number are, strictly speaking, consultation cases, the more important of which are recommended for hospital treatment. Many of these patients come from considerable distances for professional advice, and they do so frequently on the recommendation of their regular medical attendants. Cases of peculiar interest are referred to the regular hospital surgeons, so that, while primary attention is attached to the interests of the patients, such selected cases add to the importance of the hospitals as schools for clinical instruction. In so far as I have been able to observe, there is nothing whatever of a pauperising tendency in the outdoor patient department of the hospital dispensaries; and I do not think that there is any ground for complaint, on the part of medical practitioners, as to the free dispensary system, as carried out in Glasgow, interfering with professional interests. Indeed, I may state that I have never heard of any such complaint from medical practitioners, so that the Provident Dispensary system cannot be recommended for Glasgow as a remedy for evils arising out of the abuse of our medical charities. The system, therefore, of mutual assurance during health, for medical attendance and medicine during sickness, must be tested by its own merits.

For the purposes of this inquiry, the community may be divided into two great classes—viz., those who are able to pay the usual professional charges, and those who are not able to do so. The second class—that with which we have to deal—includes the pauper class, or those persons who are in receipt of parochial relief; but this class being provided for out of the public funds, and being attended by the parochial medical officers, does not come within the scope of Provident Dispensaries.

The promoters of Provident Dispensaries define the first class—viz., those able to pay the usual professional fees, as individuals, or heads of families, whose income is over 40s. per week; and the second class—viz., those unable to pay the usual professional charges, as individuals, or heads of families, whose income is less than 40s. per week. This, like all other generalizations, is necessarily imperfect; but this imperfection is met, and provision is made for obviating it, by the discretionary power vested in the committee of management, whose duty is to investigate each case of application for assurance, and to take into account, as regards acceptance or rejection, special circumstances. The divisions and the definitions thereof are merely intended to indicate the circle within which the groups of cases may be found requiring the extraneous aid of Provident Dispensaries. The outer margin of the circle is blended with the well-to-do and the opulent circle; while the centre is darkened by the hues of pauperism, and those objects of charity who have been entrusted by the Legislature to the voluntary benevolence of the public. A line must be drawn somewhere, and I can give no more satisfactory reasons for making a weekly income of 40s. the boundary of the circle, than our authorities can for defining a £10 rental as the charmed circle of exemption from the payment of certain public rates.

A man's ability or non-ability to supply himself and his family with all the necessaries of life does not depend altogether upon the rate of his weekly income. His requirements must be taken into account; and it may be found that many of those in the receipt of good weekly incomes, require almost every penny to meet charges of constant occurrence. There is often, also, a pressure brought to bear upon the wage classes which tends to force them into the vortex of pauperism—viz., those obligations under the Poor Law to support, in whole or in part, parents and descendants. This is often a burden which, though cheerfully borne, is manifestly too heavy to bear, and necessarily tends to the ultimate pauperization of the family. For all practical purposes, therefore, the 40s. per week circle, with the discretionary powers mentioned of exclusion and inclusion, may be accepted as a reasonable limitation of the area within which the Provident Dispensary Scheme may be planted and propagated.

Having thus briefly indicated the class contemplated by the scheme, it may be advisable to consider whether this class really requires any extraneous aid; and, if so, of what description, meaning, of course, extraneous aid in the matter of medical attendance.

I presume that the medical necessities of each section of society, high and low, rich and poor, are pretty much alike; but such necessities are not equally realized, and, consequently, are not uniformly applied for and supplied. Among the opulent and well-to-do classes, who are in circumstances to avail themselves of the services of a regular family physician, every case of illness, and even so-called trifling cases of illness, are promptly attended to; and those affections incidental to infancy and childhood are generally treated on the first appearance of symptoms of ill health. Attention is also given to the sanitary condition of the residence, to personal hygiene, to the maintenance of the standard of health, to the prevention of disease; and, it may be stated generally, that the family physician has the general oversight of the health of the household, as well as the treatment of disease when it does appear. Amongst this class we have a lower death-rate, and a higher standard of general health than prevails among the population generally; and, in so far as we can judge from our vital statistics, there is in progress a decided improvement. Even amongst this class, personal and general hygiene does not meet with the amount of attention which it merits; but increasing attention is being paid to such subjects, and there is reason to expect a gradual and steady improvement in the standard of public health.

The same system prevails in the households of many within the circle specially under consideration, and the same prompt attention is paid to all cases of illness. The obligations of this section are honourably and cheerfully met, and apparently with no great difficulty; but there are many who do not and cannot do so, the neglect being due in many cases to ignorance or to poverty; and, in some cases, to parsimony, or to all combined. To so-called trifling complaints no attention is paid, so that the trifling cases become serious, then dangerous, and finally fatal. Amongst many families, children's diseases—the deadly zymotic group—are either totally neglected or mistreated, under the directions of some wise old woman; and it is only when the patient is *in articulo mortis* that medical aid is called in. But I believe that there are many of this class, perhaps I would not be far wrong in saying the most of this class, who hesitate in calling in professional aid because they do not see their way to incur the expense, or to impose upon themselves obligations which they can never meet.

Dr. Russell, at page 57 of the admirable report to which I have referred, says, that of the deaths registered in Glasgow, in 1874, 3,600 were uncertified. Of these, 1,646 were admitted to have had no medical attendance, while 1,403 had been taken to a dispensary. Of the adults 65 per cent., and of the children 34½ per cent. died without medical attendance; while of the adults 13 per cent. and of the children 54 per cent. had been taken to dispensaries for treatment; and he asks—"What can be the meaning of the fact that 54 per cent. of the *children* who died 'uncertified' were 'taken to a dispensary,' and only 13 per cent. of *the adults*, while 65 per cent. of the adults who died 'uncertified' died without medical attendance, and only 34½ of *the children*, but this, that children are portable and were carried to the doctor, while the adults went as long as they were able, and when unable, died at home without further care?

"The only satisfaction to be got from such facts is this, that they indicate a desire on the part of the poor to overcome the difficulties of their position, and prove that they go in search of that which, by charitable agencies, ought to be brought to them in their own homes. Nor must we allow those numbers concerning deaths to become impressed upon our minds as giving any conception of the actual extent of neglected sickness in Glasgow. These 3,600 uncertified deaths, with their various degrees of admitted uncared-for sick beds, are simply a few of the multitude singled out and proclaimed to us by death, while 20 to 25, at a moderate computation, for each death have been sick, and have been equally uncared for. If 1,600 persons died absolutely without medical attendance, we may be sure that 32,000 had various degrees of sickness, and received no medical aid."

Dr Russell, in the paragraph quoted, writes with the view of calling public attention to the clamant necessity which exists for the extension and organization of our medical charities, so as to carry their benefits to the homes of the poor; and he calls attention to the fact that 32,000 persons, outside the pauper circle, suffered from various degrees of sickness, and received no medical aid, and that of these, 3,600 died in one year in this city, without having even so much attendance during their illness as would warrant a duly qualified medical practitioner granting a certificate as to the cause of death. Doubtless, a number of the deaths so registered would be cases of sudden death; but, were even such cases eliminated, the general deduction to be derived from the facts would not be materially altered.

The percentage of uncertified deaths in Glasgow during the year 1878 was considerably less than during 1874, being 13 as compared with 22; but we are still confronted with the same class of facts. These 1,646 cases of death, regarding which it was avowed there had been no medical aid whatever; those 552 cases in which the medical men refused to certify as not having attended the cases; and the 1,403 children whose only medical attendance consisted in being carried to a public dispensary or a doctor's shop, all belong to the class which I have introduced to your notice—viz., the class comprehended within the 40s. per week area. To the question, therefore, does this class require any extraneous aid in the form of medical attendance, we have a response in the affirmative from 3,600 graves in one year, and from 32,000 sick beds at least.

What is the meaning of these figures? The 3,600 dead, and 32,000 sick, were not isolated human beings—strangers in our midst. They represent a class, probably a large class, every one of which is being gradually drawn into the same vortex of misery. The 3,600 of one year are replaced by 3,600 the next year, and we may well ask from whence are the recruits drawn. They come, I doubt not, in many instances, from among the respectable working-classes, whose misfortunes were greater than they were able to bear; for the death of a parent often means the ruin of a family, and the death of children quite as often means the ultimate pauperization of parents; they come also from among the respectable but improvident, who live from hand to mouth, and make no provision for the future; they come also from the ranks of the reckless and the improvident, whose chief anxiety is how to avoid the payment of their just debts; they come also from the ranks of the immoral and the vicious; while a vast number belong, I doubt not, to the labouring class, whose income cannot supply them with more than the bare necessities of life.

Dr. Russell recommends the extension of our charities for the benefit of this class, while I recommend, in addition, the establishment of Provident Dispensaries; but, after all, we are agreed that extraneous aid is necessary. There are, doubtless, a vast number of individuals who are, in virtue of their social position, living on the borderland of pauperism. A man with a wife and family, whose wage does not average more than 15s. per week throughout the year, has not much to be either provident or improvident with; but even among such there may be a small margin for thrift. Dr. Russell looks upon one section of the class—viz., that which is in actual destitution, and which must be immediately relieved; whilst I look upon another section of the same class—viz., that which possesses the means of being saved from the impending evil, and say, provide yourselves against the evil day. The two agencies work towards the same end, the one from the centre towards the circumference, and the other from the circumference towards the centre. Dr. Russell, in his report, gives prominent importance to the principle of self-help, and he observes that "Independence of extraneous aid, especially medical, rests, for a large proportion of our population, on the continuity of two conditions:—1. The steady application to daily wants of every penny earned; 2. The maintenance of unbroken health, both by the bread-winner and his dependants. Unhappily, the number of those who deviate from the first condition greatly swells the ranks of those who necessarily become dependent when the second condition is invaded, as in the most favoured circumstances it so invariably is from time to time, as children multiply, and time passes."

The sole object of the Provident Dispensary scheme is to secure the second condition by the application of the first; and to do so on the principle of mutual assurance, the monthly rates of payment by the Provident members being within the means of all who are not absolutely destitute. If a family, consisting of husband, wife, and any number of children under sixteen years, cannot afford to pay, through no fault of their own, at the monthly rate of 1s. 4d. for medical attendance and medicines, then I say that that family, when invaded by sickness, are proper objects for public or private charity. This is the highest rate payable by any family, and represents an extreme case. Take the case of a widow, with any number of children under the age of sixteen: the monthly payment amounts to 7d., a rate certainly within the means of all not absolutely destitute. This also represents an extreme case; for the greater the number of children, the greater is the household expense; but these cases clearly represent the boundary lines at which private charity must come in to the rescue.

I think there can be no doubt that almost the entire wage class could, were they willing, avail themselves of this mode of assurance, so that some limits could be placed on the ever widening boundary of private charity; and it would be a great matter were we able to say, regarding every uncertified death—this is the result of improvidence or vice. But this aspect of the question is comparatively unimportant, the great merit of the scheme being that every inducement is held out for consultation regarding health, and for prompt attention to every case of illness at its earliest stage, the family of the artizan being placed on the same footing, as regards the essentials of medical treatment, as that of the opulent merchant. Under such a scheme, no case of illness would be neglected, and, were the principle extensively adopted, it would be possible to grapple with the infectious diseases of children. Of course, I cannot speak from either experience or observation as to the practical working of Provident Dispensaries, but, judging from analogous cases, I can form a tolerably accurate opinion as to their intrinsic value, and as to the important effects they would have in promoting the Public Health. In Glasgow, as in other places, there are many Friendly Societies, such as the Oddfellows, the Foresters, the Gardeners, the Shepherds, &c., which are simply mutual assurance societies for medical attendance, medicines, and aliment during sickness, and for burial money at death. These Societies are mainly composed of the *élite* of the working-class. They are not necessarily open to all comers, for candidates must be proposed, seconded, and medically examined prior to admission as members of the order. Male adults only are admitted. No member can be placed upon the sick list without being seen by the medical officer, and, as every member is entitled to aliment should he be even a day off work, every case of illness comes under immediate observation and treatment. Working-men of character and ability, such as comprise the provident class, are much more anxious to keep off the sick list, even with its inducement of aliment, than to be placed on it, and hence the medical officer is consulted in matters pertaining to health, and in so-called trifling cases of illness, more frequently than occurs in the best description of general medical practice. The consequence is precisely what might be expected—a low death-rate from acute diseases.

The best feature in the Provident Dispensary scheme consists in the fact that the interests of the medical man and his patients are identical. If the doctor can secure "the maintenance of unbroken health, both by the bread-winner and his dependants," labour and expense are saved, and in cases of illness, the more speedy and complete the recovery, the better it is for all concerned.

I do not by any means intend to convey the impression that the interest of the medical man and the patient or family necessarily, or even usually, conflict; but I mean to say that, according to this scheme, the maintenance of the standard of health, and the prevention of disease, are so obviously in the interest of the medical officer that it must be prominently before his mind; so that, by the small payments mentioned, the poorest persons may obtain advantages equal to those possessed by the richest. In this respect, therefore, the Provident Dispensary scheme is eminently calculated to promote the Public Health.

In so far as I have laid the scheme before you, I think you will admit that the advantages offered are very great to the provident members; but it may occur to you that there is an objection which may weigh considerably with some who would otherwise regard it favourably. People like to select their own medical attendants, and dislike being restricted in their choice. True; but even according to present arrangements, people are necessarily restricted in their choice; for doctors, whose practice may be confined chiefly to the working-classes, cannot afford to follow their patients when they migrate from his district; and families, when they migrate to distant districts, soon find it to be inconvenient even for themselves to send to considerable distances for their doctor. This difficulty is obviated, in so far as it is possible, by having, invariably, more than one medical officer attached to a district dispensary, and there is no restriction to the number who may be elected. Sir Charles Trevelyan, who is the ablest and most enthusiastic exponent of the system, says:—"He, the member, can select a confidential family doctor from among the medical officers of the Dispensary; in cases of serious illness, he is entitled to medical attendance and medicines; and, if necessary, to skilful and tender nursing, *at his own home;* and if he suffers from disease requiring hospital treatment, he is recommended to the general or special hospital most suited to his case. The advantage to medical men is, that there are no small bills to collect, and no bad debts, the payments being made, not to the doctor direct, but at the Dispensary; and that an opportunity is afforded for acquiring valuable experience, especially in the domiciliary treatment of disease, as well as personal favour and professional reputation. Everything in life is 'give and take,' and it is enough if a preponderance of benefit can be shown. A few small professional fees, which, after all, are expensive and difficult to collect, may have to be foregone towards the upper margin of the working-class; but, on the other hand, that entire class, stopping short only at absolute paupers, will be brought under effective contribution."

I forbear entering upon the business aspect of the question, as affecting medical men, but I may state my opinion that the establishment of such dispensaries would benefit many, and would injuriously affect none. I do not think that the medical men of Glasgow are, as a rule, overburdened with remunerative work; on the contrary, I think that their number is quite sufficient to meet the calls for their services. Perhaps some may think that there is rather a plethora than otherwise, but we find that in Glasgow, including the suburbs, there is but one practitioner for every 2,250 of population, while in Edinburgh there is one for every 1,000 and in Liverpool one for every 1,500. The numbers per 1,000 of population in Glasgow who receive charitable medical aid are 72, while in Edinburgh there are 200, and in Liverpool, 236. From these facts, Dr. Russell concludes:—"(1) That the work done by such charitable agencies is work which, if not so done, will never be done at all; and (2) That the private interests of the medical profession are not invaded by even the most complete system of medical relief." From the same facts, I conclude that the field for Provident Dispensaries is virtually, in great part, new ground, and that the cultivation of it will not interfere with the private interests of the profession.

The interests of the medical profession may, and probably would, be invaded in a very serious manner by introducing a system of gratuitous medical aid to all who may choose to avail themselves of it, but never by the introduction of the Provident Dispensary system.

Of all the systems of medical relief, the semi-charitable is, in my opinion, the worst. In Liverpool there are, in addition to the hospitals and attached dispensaries, three so-called medical charities, the North, South, and East, which are amalgamated under one committee of management, with a paid secretary and central office. To each dispensary there is attached a staff, the total consisting of 13 consulting medical officers, 17 ordinary medical attendants, 3 resident house surgeons, and 4 apothecaries. The poor are attended at their own homes, and medicine is supplied in all cases. Patients are attended to on the presentation of "recommendation slips" signed by a subscriber to the charity. In 1874, medical attendance, with medicine, was supplied to 20,575 sick persons in their own houses, and advice and medicine at their dispensaries to 52,760 more, at an expenditure, per patient, of 1s. 4d. for all costs, of which 7½d. was for salaries, and 4d. for medicines, the total expenditure being £4,870. Regarding Bristol, Dr. Davies, medical officer of health, says:—"Every man in Bristol can procure medical advice and attendance for himself and family most easily, by applying to his employer for a dispensary ticket, to which almost all employers in Bristol subscribe; by joining benefit societies; or by getting a note for the Royal Infirmary or General Hospitals." This system looks well; indeed, it seems to be highly satisfactory; but, while it remedies one evil, it creates and perpetuates another of much greater magnitude. We are practically unacquainted, in Glasgow, with this mode of dispensing medical charity; and, should it ever be introduced, great caution would be necessary. Almost all employers, it is said, subscribe to the charity; and when one of the employed, or of his family, falls sick, he can easily secure medical advice and attendance by applying to his employer for a dispensary ticket. I have no right to exclude motives of pure benevolence from the subscribers to such charities, and in all probability the gift is to many an act of pure benevolence; but it is liable to great abuse, and it could be made a mode of paying-in a pound and receiving change on very advantageous terms. *If you are satisfactory to me, I can give you and your family, in addition to your weekly wage, medical attendance and medicine free of charge; but, if not, then——.* Where does the charity come in, either on the part of the giver or receiver? Small shopkeepers, who drive a business chiefly among the working-class, subscribe also to the charity, and the tickets at their disposal are distributed among their customers.

This certainly looks like getting change for a pound note, with the addition of a certificate for practical benevolence. This is not charity—it is traffic; and it is trafficking, on the most favourable terms, with the services of the medical profession. It is possible to pay too much for an article, though no money may change hands; and it appears to me that this article of medical attendance and medicine is purchased by the sacrifice of independence, and the consequent loss of self-respect, which is the greatest loss which any man can sustain; for, when a man loses self-respect, there is not much left. When a man is a pauper, not from necessity, but from choice, he is gravitating towards a condition from which the element of choice is eliminated—a condition of necessary pauperism. Every scheme which has a tendency to pauperize, however benevolent its title may be, should be regarded with more than suspicion; but a similar scheme, based upon "thrift," commends itself to every right thinking man, the only question being, Is it practicable?

I believe that there would be no great difficulty in successfully introducing the Provident Dispensary scheme into Glasgow; but it would require a distinctive agency. Various administrative arrangements have to be made before the scheme can be placed upon a basis sufficiently solid to commend it to public confidence; and pecuniary aid would be necessary until a sufficient number of provident members had joined to make it self-supporting. There are, within the district of Glasgow, at least 20,000 men, most of them heads of families, in connection with the various friendly societies, who are fully alive to the advantages of medical relief, on mutual assurance principles, and who are thoroughly acquainted with the practical working of such societies. Many of these would, I doubt not, favourably regard the introduction of any such scheme, and would give it their hearty support. Indeed, the co-operation of this class would be essential to the success of the scheme; and, were it once set agoing, I believe that it would be best to leave the carrying of it on in the hands of the provident members themselves. The success of the great provident societies, here and elsewhere, is a sufficient guarantee that those immediately interested can best manage their own affairs, and this class like to do so in their own way.

Would the initiation of this scheme be worth the trouble and expense? I think it would, on various grounds and for many reasons. I shall confine my concluding remarks to one, not the most important one—viz., its relation to the Public Health. As members of society, we must confront these 3,600 untended deathbeds, and these 32,000 uncared-for sick beds. Do what we will we cannot shirk our obligations. We are responsible, probably to a greater extent than we are willing to admit, for both the misfortunes and the vices of this class, and also for their resulting miseries. The most expensive mode of performing our public duties is neglecting to perform them; by-and-by the tax-gatherer will call and we will require to pay, with interest and expenses. If the head of a family dies through public neglect, the account is not settled when the undertaker and gravedigger are paid. There may be another account to settle, on behalf of a neglected family, from the poorhouse, the prison, and perhaps from the hangman. The ramifications of such matters are wide, and may extend so far that we are unable to trace them. Neglected disease of any kind is necessarily a serious matter; but more especially is it so with neglected disease of the infectious and contagious class. Such diseases could be easily rooted out, so that they would finally disappear from our West-End houses; but this is not enough. There is no safety for the West End so long as the East End is neglected; no safety for the rich so long as disease is allowed to run its course among the poor. Every man is his brother's keeper, and no one is rich enough to pay for a substitute. Obligations of this kind cannot be delegated. So long as the health of the poor is neglected, the health of the rich is not safe; and the connection between the hovels of the one and the villas of the other is much closer than most of us imagine. Lazarus, in stern reality, sits at the rich man's gate, and the dog that licks his sores may lick the children's hands. Human nature is stronger than the order of a mistress; so that a maid may, on her afternoon out, nurse a little brother or sister sick of scarlatina or diphtheria, forgetting that she may carry disease and death to the family whom she serves. Who can blame her? Was she warned, while tending the sick child of her mistress, against carrying infection to the little ones of her own family?

Our only mode of safety from the ravages of epidemic diseases consists in attacking them in the centres from which they spread; but this can never be done by medical officers of health and sanitary inspectors alone. The entire population must be brought under medical surveillance, and I can see no better mode of doing so than by the promotion of some such scheme as I have laid before you. The registration of disease would then be a possibility, and what are now regarded as the day-dreams of sanitarians, would gradually assume the substantial form of realities.

XII.—*On Improvements in Gas Stoves.* By JAMES ADAMS, M.D., L.R.C.S.E., F.F.P.S.G., Late Examiner in Chemistry, Fac. Phys. and Surg., Glasg., Late President of the Glasgow Medico-Chirurgical Society, &c., &c., &c.

[Read before the Society, March 17th, 1880.]

TWENTY-FIVE years ago I read to the Glasgow Medical Society a communication on heating by gas, and exhibited a stove made to my design. In my belief that stove surpassed anything since open to public observation. But it was liable to drawbacks, which I then failed in overcoming, and I put aside my conception. I retained, nevertheless, the desire to see it realized, being sensible that I had made a substantial step in advance, and I have kept myself informed, and noted with interest all that has since been done in this connection. About eighteen months ago I re-entered with zest upon a practical investigation, feeling assured that the principles were sound that I had assumed for my guidance, and had practically embodied in my infant conception. I will now bring under your consideration a practical illustration of those principles.

Coal gas is not of uniform composition. It is a mixture of gases and of vapours, the number, qualities, and proportions of which vary in every locality where coal gas is manufactured for public use. Its most abundant constituents are compounds of carbon and hydrogen—the latter forming the bulk of the mixture. However carefully manufactured, impurities are always present, which, together with the gaseous waste products of combustion, should never be permitted to accumulate in the air of dwelling apartments. When coal gas is burned its constituents are transformed into other gases and vapours. On this point there is much popular ignorance. Because no smoke, and no marked odour may be perceptible, it is assumed that the combustion has left behind it nothing injurious. There is a hazy conception that perfect combustion means something like practical annihilation. But in point of fact, the invisible, mal-odorous, inflammable gas, has been merely transformed into invisible, non-odorous, non-inflammable gas. The carbon has united with oxygen of the atmosphere, and formed carbonic acid—a deadly poison if inhaled pure—and the hydrogen has united also with oxygen of the air, and formed watery vapour, whilst a large quantity of nitrogen has been set free from the air. But if combustion has not been perfect, there is formed, in addition to carbonic acid, another still more poisonous gas, called carbonic oxide. The common sense deduction is that gas stoves should be provided with flues to carry off the waste products of combustion into a chimney. It should scarcely be necessary to add that, where a stove is substituted for a grate as a means of heating an apartment, there should be retained the open chimney, or other means of proper ventilation which the open fireplace usually ensures.

The amount of light obtained by the combustion of coal gas varies according to the construction of the burner employed. The same gas which gives a pure yellow smoky flame when burned with a "rat tail" jet, is brilliantly white when a union jet is used, still brighter with a common argand, better still with a Sugg's argand; while in the latest street lamp introduced in Paris, and of which several are now under observation in this city—we seem to have reached a perfection that rivals the electric light. The production of heat—which as a force is identical with light—is quite as much influenced by the form of burner employed. And as the phenomena of light require to be considered with reference to the luminous rays, the chemical rays, the coloured rays, &c., so do the phenomena of heat require to be considered with reference to dark rays, visible rays, and other components or characteristics. Thus the several properties through which heat is communicated—viz., conduction, convection, and radiation—have each their special value and appropriate use, and ought to be carefully studied, so as to best ensure the maximum intensity of each property as well separately as in combination. A kettle over the fire is boiled partly by convected heat contained in the diffuse mass of flame and smoke ascending the chimney, and partly by radiant heat emitted by the solid incandescent coal underneath. But a leg of mutton placed in front of the same fire receives no heat whatever from *convection*, but is roasted exclusively by *radiant* heat emitted chiefly from the red-hot coal. A very small proportion only of radiant heat is emitted by the flame and smoke. By accurate observers it has been determined that about three-fourths of the heat from an open fire is convected heat, nearly all of which passes up the chimney, leaving only a fourth to be utilized as radiant heat. When coal gas is used as fuel, and the ordinary jet for lighting purposes employed, the convected heat generated amounts to 84 per cent., or five-sixths of the whole, and only 16 per cent., or about one-sixth, is given out as radiant heat. When the Bunsen burner, in any of its forms, is employed, the heat generated is nearly altogether that of convection, about 6 per cent. only consisting of radiant heat. The difference in the proportion of radiant and of convected heat, emitted by the same gas by a mere change in the method of combustion, depends on the presence of solid carbonaceous particles in the luminous flame. This question has been thoroughly worked out by Tyndall, and the results are recorded in his "Contributions to Molecular Physics in the domains of Radiant Heat." Using an apparatus of sensitive precision, he found the radiation from the luminous gas flame was fully two-and-a-half times that from the non-luminous flame. The degree of *force*—not the degrees of temperature—in the luminous flame was 30, and the radiation fell to a force of only 12 the instant the flame became non-luminous. But, by introducing solid matter, the radiation originating in the non-luminous flame became so intense that a spiral of platinum plunged in the flame brought up the index to a force equal to 200—that is, there was instantly generated an amount of radiant heat more than 6 times that from the luminous gas flame, and more than 30 times that of the non-luminous flame. "It is mainly," says Tyndall, "by convection that the hydrogen flame dispenses its heat; though its temperature is higher, its sparsely-scattered molecules are not able to cope in radiant energy with the solid carbon of the luminous flame. The same is true for the flame of the Bunsen burner. The moment the air (which destroys the solid carbon particles) mingles with the gas flame, the radiation falls considerably. Conversely, a gush of radiant heat accompanies the shutting out of the air, which deprives the gas flame of its luminosity. When, therefore, we introduce a platinum wire into a hydrogen flame, or carbon particles [or platinum, or various other solids] into a Bunsen flame, we obtain not only waves of a new period, *but also convert a large portion of the heat of convection into the heat of radiation.*"

To obtain in a practical form the means of converting the heat of convection into the heat of radiation has been the chief aim of my efforts for the improvement of gas stoves; and I will now give a short description of the method through which I accomplish my object.

I employ in gas heating stoves a burner consisting of a group of hollow perforated tubes or forms of fire-clay, supplied internally with a mixture of gas and air, which, passing through the perforations, burns on the outer surface. These fire-clay tubes are enclosed in a case or chamber, which prevents free access of air to their exteriors, where combustion is completed; but, by perforations, a small and suitable quantity of air is admitted, which ascends within and between the tubes, and ensures complete combustion that causes the fire-clay tubes to become brightly incandescent. Thus only the smallest practicable excess of unconsumed air is permitted to mix with the products of combustion. These products are led to a chimney by a flue of peculiar construction, in which they are detained until they have parted with all their available heat. Other channels or ducts lead currents of pure air along the heated walls of the flue channel; and the air so warmed is allowed to re-enter the room in which the stove is used. The walls of the air channels or ducts, and generally the casings of the stove, present an extensive surface, obtained by duplications of the casings, to take up the heat from the products of combustion traversing the flue channel, and consequently their surfaces do not become overheated. The air entering the stove is caused to pass in at or near the top, and thus a supply free from dust is ensured, and draughts along the floor of the apartment are avoided. The warm air issuing from the stove is caused to pass over water contained in a trough, so formed that, by filling it more or less, the surface of water exposed to the warm air may be varied. Lastly—not to dwell on too many points—provision is made by which the risk of explosion is entirely obviated.

The time at my disposal will not admit of a detailed account of the arrangements by which the exact consumpt of gas necessary to produce the full efficiency of the stove is regulated with automatic precision, and by which the quantity of air necessary for perfect combustion is also supplied efficiently and automatically. I will only say on this head, that air is admitted to the combustion chamber by small apertures of carefully-regulated size and fixed number, corresponding to the designed supply of gas—that the air is projected in fine jets—and that it is so diffused that all, or nearly all, is brought into actual contact with the gas fuel, and in the right proportion. The stove when in use is always in efficient action, and when the full heating power is not desired the heat may be diminished precisely as the light of a gas jet is increased or diminished at pleasure.

Knowing that an enormous amount of the heat produced by gas combustion, whatever the method employed, consists of, or rather is lodged in, the molecules of gases and vapours that form the waste products, I deprecate the common practice of letting them go at large into the atmosphere, or sending them by the shortest cut up the chimney. But as a portion of the waste products consists of water in the condition of vapour which at a temperature under 212° F. will condense and trickle down as water—and that another portion consists of carbonic acid, which at the same temperature is more than half again heavier than air, and will not ascend the chimney unless in a heated and expanded condition—there is a necessity that I should let some of the heat go. As the result of numerous practical experiments, I have determined that the waste products should be passed into the chimney at a temperature not under 212° F., and not above 250° F., and nearer the latter than the former temperature. The average temperature under my arrangements exceeds 240° F. But these waste products have an initial temperature exceeding 2000° F., and to extract from them all the heat that is desirable, I cause them to traverse a flue of peculiar construction—a flue *sui generis*. It is of *great length*—consists of superimposed *horizontal* chambers—these chambers communicate by *contracted openings*—and the walls of the flue are fitted with *baffle-plates*. Each of these peculiarities has a separate action and marked influence; and the combined result is to cause the waste products to travel slowly at a mean temperature, and to force the gaseous molecules into that individual contact with the walls of the flue that is absolutely necessary before they can impart their contained heat. The heat transmitted by conduction through the flue walls to the outer surfaces of the flue is also diffused by conduction over a large surface area of duplicate casings. The pure air led over this extended surface is warmed to the temperature obtained under the most approved systems of warming by hot water or steam pipes, although, when desired, the heat may be greatly increased. The quantity of air warmed is very much beyond that of stoves of much greater external size. Thus a stove of ordinary construction has, we will assume, an external heating surface of 16 square feet. The same size externally, but made to my design, has, in addition to the external surface, an internal surface of 26 feet, making a total of 42 square feet—that is, a surface equal to 42 linear feet of a 4-inch hot steam pipe.

In my opening observations I stated that I had laid aside my conception of a gas stove many years ago, owing to serious drawbacks which I failed at the time to overcome. One of these was the danger of accidents by explosions. Such accidents occasionally take place on the incautious application of a light some little time after the gas has been turned on, or has otherwise been escaping and forming an explosive mixture of gas and air within the stove. The construction of my stove makes accident an impossibility. The entire "motor force" of the stove consisting of the furnace chamber, with all the subsidiary fittings for the admission and regulation of air, &c., are attached to a closely-fitting drawer or tray in the base of the stove, made capable of sliding out and in from the interior. When the drawer is withdrawn—as will always be unavoidable for lighting purposes—air is at the same time freely admitted, the stove is instantly ventilated, and any mixture of gas and air accidentally present is deprived of its explosive properties. Although a considerable interval may have elapsed between the turning on of the gas no explosion can occur. These arrangements ensure—1. That the stove is efficiently ventilated and free from an explosive accumulation of gas and air before a light can be possibly applied; 2. that the gas can only be ignited in the unconfined air of the apartment, openly, and therefore safely; 3. that the entire "motor," with its subsidiary mechanical arrangements and connections, is freely exposed to observation on every occasion that the stove is used, and therefore that any defective condition of the gasfittings or other working parts can be instantly recognized, and, if need be, remedied.

Several modifications of the construction of my hot-air stove have been designed. That which I now exhibit is a plain working model. It is for manufacturers to employ artistic devices for the outward forms, and to construct smaller or larger sizes to meet popular requirements. As the "motor force" is of the exceptional power of which I will presently give evidence, it is capable of being applied to a variety of uses for which high temperatures are required, such as cooking, laundry and tailors' stoves, conservatories, bakers' ovens, and, in short, nearly all the purposes for which coal itself is usually applied.

It has been pressed upon me to discuss here the important question of cooking, and to give some description of the modification of stoves I have designed in this connection. But that matter must be reserved for more special and full consideration than can be given on the present occasion. Hitherto I have been treating of the best method of *generating* heat within a stove by the combustion of coal gas, and the best method of *distributing* that heat *outside* the stove. For cooking and for analogous uses the principles of construction differ entirely. The objects I have aimed at in cooking stoves are—1. To prevent the distribution of heat *outside the stove;* 2. to ensure a more effective use of convected heat than hitherto; 3. to utilize the properties of pure radiant heat in a degree to which no existing gas stove can make pretension; 4. to devise cooking utensils specially applicable to gas stoves, or at least more suitable than any I find in ordinary use. That there is scope for improvements may be inferred from one illustration having reference to the conditions under which cooking operations are generally performed, and which will show that there is more matter for consideration in the subject than is dreamt of in the philosophy of stove manufacturers in general. At the recent Gas Exhibition at Greenock, Mr. Stewart, M.P., while heartily desirous to aid the movement, stated that, "from what he had experienced of food cooked by gas, *there was always a something left behind* which one would rather have been without." Some light may be thrown upon the cause of this peculiar undesirable "something" if we examine the arrangements made by the best stove makers. In roasting meat the burners are placed at the bottom of the oven, and the joint is suspended above, and then, in the words of the usual advertisement, the meat "is completely enveloped in an atmosphere of heated AIR, ... the joints when cooked have very much *the same appearance* as those done before an open fire, but they lose rather less in weight, are plump and full of gravy," &c.; and, finally, it is stated that, "in the roasting of a 6 lb. joint there is burned 30 cubic feet of gas." But is the meat roasted? Is it not rather what may be called gassed? It is not an atmosphere of heated *air* that envelopes the meat, but an atmosphere of hot waste gases, watery vapour, sulphur, tar, and other impurities, the products of gas combustion. Setting aside the gaseous impurities, may not the watery vapour alone have a share in producing this peculiar "something"? The combustion of 30 cubic feet of gas of average composition generates above 2 lbs. avoirdupois of pure water in the shape of steam vapour, and it is therefore easy to understand why the meat does not lose so much weight in the gassing process. It is already surrounded with *a watery atmosphere* that lessens evaporation. If the meat had been roasted before a clear fire, and a pan of water holding 2 lbs. had been boiled and evaporated into steam underneath the joint, the two processes would have been perfectly analogous, with the exception that in the gassing process there is mixed with the watery vapour some 200 or 300 cubic feet of the waste products of gas combustion. These are facts worthy of being pondered over, and so I leave them.

I will now cite some evidence of the efficiency of my hot-air stove. And here, if I confined myself to a bald statement, that so many units of heat are utilized in the combustion of so much gas, you would—at least, many would—be little the wiser. To appraise the statement you must know the value of the units, and have some standard or data for comparison. The standard in this country is that amount of heat which will raise the temperature of 1 lb. of water by one degree at 32° F. It may equally be reckoned in grains or ounces, grammes or litres, but 1 lb. is usually assumed. This standard is not conveniently applicable to determining the calorific force of a gas stove. The specific heat of air, its weight per lb. at every degree of temperature, the quantity of moisture it contains, the material of which the stove is composed, the shape in which it is fashioned, the absorbing power of the walls and other surroundings, &c., all form so many factors which must be taken into account. Then there is necessary a variety of formulæ, tables, and other data, close at elbow on every occasion, and on which are based arithmetical calculations, so intricate, tedious, and complicated, that very few individuals, although otherwise well-informed, can follow out perfectly the series of operations which go to the taking of a single test. So numerous are the fallacies to which the working of the rules are liable, that none of my chemist friends consider them practicable for ordinary use. But they all are satisfied that the method I adopt, although not perfectly accurate, is perfectly fair and perfectly sufficient in determining approximate values, and for ordinary purposes of comparison. I take the temperature of the air *delivered*, and deduct the initial temperature. I measure by an anemometer the quantity of air that *enters* the stove to be warmed. I multiply the cubic feet of air by the degrees of temperature it has *gained*, and call the product units of heat. Thus, 1000 cubic feet of air, we will assume, enter the stove at 40° F., and leave it at 240° F. Deducting the 40° of initial heat, there remain 200°, which I multiply by 1000 cubic feet of air, and the product is 200,000 *units*. If the gas burned has been, say 5 cubic feet, I divide the gross product by 5, which gives a quotient of 40,000, and I say, that one cubic foot of gas has yielded 40,000 units of heat. The method is simple, easy to be practised by persons of ordinary intelligence, and it is sufficiently near the truth for all practical uses.*

But it is of greater importance to determine how far the units of heat produce the desired result, seeing that they may fail for want of concentration or right direction. Reckoning the units of a man's force, there were at Ulundi some 1200 British units, and some 20,000 Zulu units, and yet the lesser number proved the most effective. Gunpowder has great potential force, and a few grains will propel a pistol bullet through the pannel of a door, but it will not open or close the door. A child of 3 years old will open or close the door, but cannot force its hand through the pannel. A tallow candle contains the potential force of many units of heat, but burned as a candle will not boil a kettle. It is the manner in which a force is localized and applied that gives the true measure of force in its relation to our present subject; and I therefore place little value on a parade of units of heat, unless associated with evidence of the effect produced in the desired direction.

I will now show that, whether in the number of heat units generated, or in the production of the heating result derived, there is obtained in my hot-air stove a development of calorific force in gas stoves not hitherto approached. And this will be best done by comparison.

I select the best hot-air stove I have tested (and I have tested many that were not worth the trouble of a test), or that has been publicly tested, so far as I know. That to which I refer, and which I will call No. 1 stove, had much attention directed to it a few months ago. It was tested, at the instance of the manufacturer, by Mr. Joshua Horton, of this city, who has, you are aware, made gas matters a specialty, and who aided me some

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* Taking the extremes of 32° and of 52° F. for initial temperatures (and it is difficult to suppose a wider latitude in actual use), and making two calculations, the first according to the usual formulæ, and the second according to my simple method, there is only a difference of less than 4 per cent.

18 months ago in various tentative experiments. The result of his tests upon No. 1 stove caused him to abandon in despair a gas stove he had himself contrived, and to express to me in private his opinion that I also should give up. This No. 1 stove was also tested by Mr. J. L. Bruce, architect, whose special knowledge of all pertaining to this subject is known to the Society. He certified that, with the exception of one of my rough working early models (which he had been privileged to examine while engaged in the investigation on the heating of Turkish Baths, an account of which is published in the *Transactions* of this Society), he had not seen a gas stove at all equal to that to which I am now referring. The certification of these gentlemen—excluding reference to my stove, which was not then open to public inspection—have been made public by the manufacturer as testimonials of merit, and my reference to these public facts is therefore legitimate. I afterwards, in conjunction with Mr. Bruce and with Mr. Harvie (the well-known ship lamp manufacturer, and also of large experience as a maker of stoves) tested this stove. Our tests were frequently repeated, and we are agreed. Mr. Bruce, in testing, prefers the use of some of the elaborate and complicated formulæ I have referred to, and the results he brings out, although not exactly in accord with mine, are so near as to make the difference of little importance. Substantially we are in accord.

Selecting the chief items from an elaborate series, I present them in the form of a table which will be easily understood.

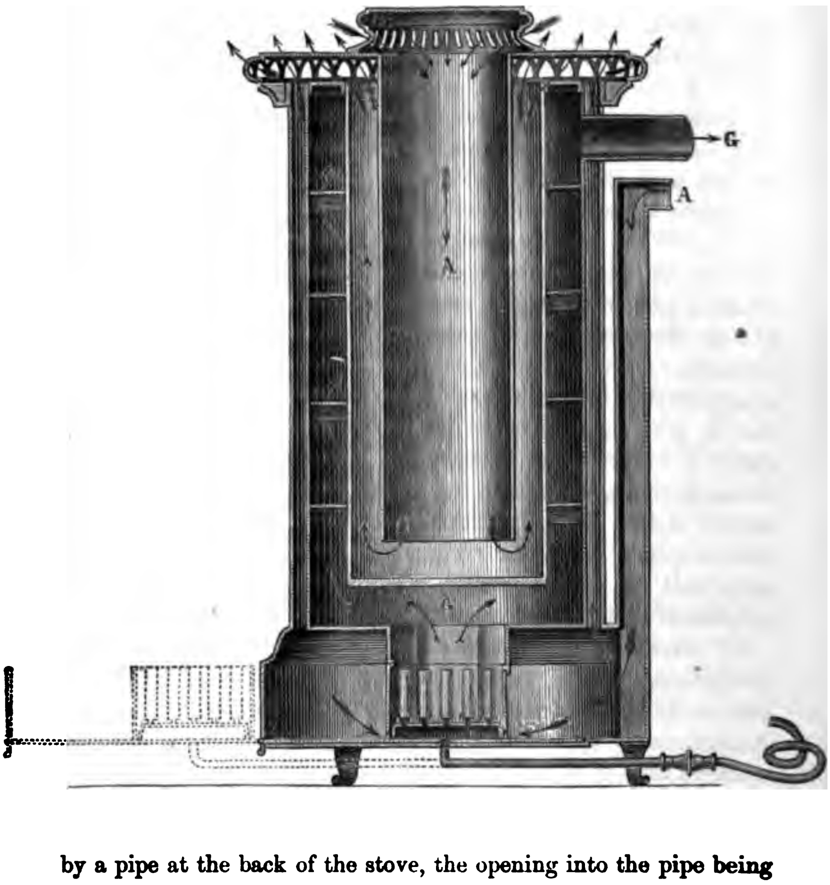
	Square Feet of Heating Surface.	Units of Heat utilized per Cub. Foot of Gas.	Temperature of Air warmed above Initial Heat.	Cubic Feet of Air warmed per Cub. Foot of Gas.	Temperature of Waste Products.
No. 1 Stove, presumably best in market, burning 10½ Cubic Feet of Gas per Hour, . . .	15	3658	62°F.	59	170°F.
Do. 13½ do., . . .	,,	6336	132°F.	48	200°F.
No. 2 Stove, Dr. Adams' New Model, burning 12½ Cubic Feet per Hour,	42	51,300	180°F.	285	244°F.

In this table the units of heat utilized *by radiation and contact of air from the external surfaces of the two stoves are not calculated.* But as No. 2 has 3 feet additional external surface, and a much higher temperature throughout, any mode of calculating the additional heat shows a very large increase due to No. 2 stove. Similar tests made with cooking stoves made to my designs show, in comparison with others, a similar ratio of results.

It will be asked how I account for this vast difference. The explanation will be obvious when I remind you of two conditions already discussed—viz., *first*, the mode in which the heat is *distributed; second*, the quality of the heat that is *generated.* A Bunsen flame, you will recollect, is composed of a current of gaseous molecules which will only give up their heat to a stove if the walls are made big enough or the flue long enough. This has not been understood, and the practice is to let them escape into the atmosphere or up the chimney as speedily as possible. The heat contained in these molecules is further wasted by being diluted and cooled through the admission of large quantities of cold air, many times larger than is necessary for mere combustion. These defects are removed in a great measure when the same form of Bunsen burner employed in No. 1 stove is transferred to No. 2 stove. There is then effected an instant and great improvement. There is utilized 210,000 units of heat per cubic foot of gas, and there is heated 183 cubic feet of pure air 115° above the initial heat for every cubic foot of gas. This great advance over No. 1 stove is fairly attributable to the novel construction of the stove casings of No. 2, and is irrespective of the burner, because in both cases the same form of burner was employed. But this improvement does not sufficiently balance the defects inherent in any Bunsen burner hitherto employed when applied to a hot-air stove. The Bunsen is liable to "strike back," run down, and burn with a smoky flame—to be suddenly extinguished by strong currents caused by the opening or slamming of a door—by "a blow down" in the chimney, &c.; and it is incapable of generating in the useful form the quantity or quality of heat generated by the *Atmopyre* burner. The novel construction of No. 2 stove, with the Bunsen burner removed and the Atmopyre burner and new combustion chamber substituted, gives an additional enormous increase in the heat utilized, for there is now utilized 50,000 units per cubic foot of gas, and there is heated 285 cubic feet of air 180° above the initial heat per cubic foot of gas. In accounting for this additional extraordinary increase, I again remind you that the *quality* of the heat generated in the new combustion-chamber differs very greatly from that generated by the Bunsen. Instead of the merest percentage of radiant heat there is now generated a substantially large proportion, and that of the most intense energy. The Atmopyre burners become so vividly incandescent as to be nearly white hot, and the walls of the combustion-chamber become incandescent. This heat is not and cannot be carried off in currents, but is instantly distributed in straight lines. Instead of being loosely diffused in a cloudy current of vapour, it is concentrated and localized in a compact solid reservoir, which is continuously being replenished, and from which the radiant heat is drawn off through the absorbing walls of the furnace chamber. From the walls of the furnace chamber it is communicated to the walls of the pure air chamber, which is continuously traversed, and the walls bathed by large currents of fresh air receiving heat by actual contact with the walls, and the air thus warmed is rapidly delivered to the apartment through the wide open vomitories of the stove. While the Bunsen burner is, in like manner with an ordinary gas jet, a mere mechanical beak or outlet for delivering the fuel, and in no sense a source of heat in itself, but only effective in the production of convected heat, the Atmopyre, on the contrary, becomes in itself a source of heat, and is effective not only in generating intense radiant heat, but is powerfully effective also in producing convected heat. The Atmopyre burner in its chamber never strikes back, is not liable to be extinguished by strong currents, whether in the apartment or in the chimney, and cannot indeed be extinguished except by turning off the gas. And so intense is the heat accumulated in the incandescent Atmopyre, that for several minutes after being shut off the gas will re-ignite if again turned on.

In concluding this recapitulation of results of a practical investigation, I desire to say that only my chemist friends, who have at different stages aided me with their corroborative counsels, can adequately appreciate the laborious details involved in giving practical form to theoretical conceptions; and to Mr. L. Mayer, of the Tharsis Co., to Professor Dittmar, to Dr. Wallace and Mr. Tatlock, the City Analysts, and others, I owe much obligation. To Mr. Harvie, ship lamp manufacturer, Broomielaw, who made my first stove 25 years ago, and who made the working model now before you, I now refer parties who may wish to have closer and more leisurely inspection, or more detailed information.

The accompanying drawing shows, in section, the chief peculiarities of one modification of a hot-air stove for warming apartments, warehouses, conservatories, &c. The hot gaseous current formed by the ignited gas in the furnace chamber is shown by forked darts traversing the series of chambers, and contracted openings, to its final exit by the flue leading into the chimney, and marked G. The course of the pure air which enters the stove to be warmed is indicated by feathered arrows. One supply enters by a pipe at the back of the stove, the opening into the pipe being marked A, and passing down to the air chamber at the base of the stove, gives off a small supply to the furnace chamber for combustion. The main stream is seen to pass upwards between the outer duplicate casings and to be discharged at the top. A second supply enters at the summit of the stove, and following the course



of the descending arrows till the current of air becoming heated at the bottom of the hanging tube is reversed and ascends, passing out at the top. The dotted lines at the base of the drawing represents the arrangement for preventing the possibility of explosion. The entire furnace chamber is drawn out on a sliding drawer, so that the gas is inaccessible, and cannot be lighted except openly in the unconfined air of the apartment, when it is no more liable to explosion than an ordinary gasalier.

DISCUSSION.

Dr. WALLACE, F.R.S.E., Gas Analyst for Glasgow, said—There are three requisites in a gas stove: First, it should have a chimney to carry away the products of combustion, without which it is objectionable in the highest degree. Second, the gas should be burned with as little air as possible. The theoretical quantity of air required to burn gas varies from 8 to 10 volumes, according to the quality of the gas: in practice a little more is necessary, but most gas stoves use an enormous excess of air, thus carrying up the chimney heat that ought to be applied in heating the apartment. Third, the waste products of combustion should be cooled down before passing up the chimney as far as may be safe to prevent condensation of water in the flue or chimney. I consider 240° F. about the proper point, but in some cases it might require to be a little higher. Viewed in regard to these three essential requirements in a good heating gas stove, Dr. Adams' apparatus is the best I have seen, and approaches as near to perfection, probably, as is attainable in actual practice. With regard to the water-vessel at the top of the stove, I do not see that it is necessary. The air is not drier in an apartment heated by a gas stove than it is in one warmed by an open fire, and the air in an inhabited room is more usually too humid than too dry. Of course, those who did not wish moist air had only to omit filling with water the trough running round the top of the stove, and thus the provision for moistening the air was no objection whatever to the stove itself. He congratulated Dr. Adams on having brought to pefection an apparatus of great public utility.

Professor DITTMAR said that Dr. Adams' stove, to say the least of it, was founded throughout upon sound scientific thought, and this, taking gas stoves as gas stoves were going, was giving it high praise. To select a set of "Atmopyres" for the generation of the heat was the happiest choice that could have been made. The Atmopyre offered this great advantage, amongst others, that it retained within itself, and thus localized at the right place a considerable portion of the heat, which, in the case of a "Bunsen," for instance, would get wholly diffused throughout, and carried along with, the large stream of gases and vapours resulting from the combustion. And in Dr. Adams' stove a considerable percentage of the heat necessarily retained by these combustion gases was coaxed out of them by means of the system of circuitous canals through which they have to travel before they are allowed to reach the chimney, the heat abstracted assuming ultimately the form of a stream of *pure* hot air.

Dr. Adams so arranged matters that these gases enter the chimney with a temperature of about 250° F.; for this reason, amongst others, that the gases "must be kept above 212° F., at any rate, to prevent *condensation of steam.*" This, in the speaker's opinion, was a mistake. The steam in the gases, being largely diluted with incondensible gases, was at a mere fraction of an atmosphere's tension, and consequently would stand refrigeration to far less than 212° F. It would condense only when cooled down below that temperature at which water boils under that fraction of an atmosphere's pressure.

There was one other point in which he could not quite endorse Dr. Adams' views; he referred to the Doctor's mode of measuring the useful heat furnished by a gas stove. He (the speaker) believed in the old established unit of heat, and in his opinion the correct method for measuring the utilized heat was, to determine the volume of combustion gases going up the chimney in terms of unit of gas burned, from their temperature and composition to calculate the number of units of heat which they take away with them, and to deduct this quantity from the total number of heat-units evolved in the process of combustion. This latter quantity of course would, strictly speaking, have to be determined directly; it would be *calculated* only from a sufficiently complete analysis of the gas.

But, after all, the best proof of the pudding was by the eating; and a similar principle might with propriety be adopted in the case of gas stoves. He had had the privilege, some time ago, of assisting in such a practical testing of Dr. Adams' stove in the inventor's house. He found the stove to produce a comfortable heat in the room at a very small expenditure of gas. He was, in fact, so much delighted with the performance of the stove that he at once decided upon procuring one for his private laboratory, where, he felt sure, it would render excellent service, as indeed it was bound to do, wherever the attending to a fire was felt as a nuisance, and the absolute absence of smoke, dirt, and dust was a consideration.

In conclusion, the Professor congratulated Dr. Adams on the excellent hit he had made, and expressed the hope that, unlike the majority of inventors, he would derive from his invention the material benefit which he was so fully entitled to.

Mr. HARVIE explained that there was a practical necessity for the high temperature of 250° F., or thereabout, in the products of combustion which passed into the chimney, for the creation of a sufficient draught in the chimney, irrespective of chemical theories or other considerations.

Mr. BUCHAN, Sanitary Engineer, commented on the high cost of gas as contrasted with ordinary fuel, and, after some remarks of a general nature by Mr. JOHN MAYER, F.C.S., and Mr. G. W MUIR, Coalmaster:—

Mr. J. HAY, Heating Engineer, thanked Dr. Adams for his emphatic recognition of the need for a chimney for *all* gas stoves, in order to carry off the poisonous gases that were generated in the combustion of gas. This was the more welcome considering that, through ignorance or other causes, there had for many years past been a succession of inventions or forms of gas stoves unprovided with flues, and in which the chief claim usually put forward was that there was "no smell," so complete was the combustion and therefore no need for a flue. Such parties neglected, or were ignorant of, the fact that just because there was no smell, and because the combustion was complete, the poisonous carbonic acid that was formed was all the more deadly and insidious, and ther was so much the greater reason that there should be a flue. H held that it was quite right that the gases of combustion shoul be passed into the chimney at a high temperature, because by bein further cooled down, they would lose their ascending power. I illustration, he cited the experience gained many years ago in th case of the Arnott Stove, where at times the combustion cam absolutely to a standstill from the want of sufficient power in th gases to ascend the chimney. He did not, however, agree wit Dr. Adams in his mode of introducing the pure air, to be heated within the stove, from a high level, nor did he see any advantage in "torturing the air" by making it pass through these up and down channels. On the contrary, he thought it would be an improvement if the air was drawn directly from the level of the floor, and better still if from the outer atmosphere.

Professor DITTMAR again rose, and directed attention to a point which, obvious as it was, had been left entirely unnoticed by the several speakers. The absolute weight of steam contained in a given quantum of a given air, of course (as Dr. Wallace correctly said) was independent of temperature; but it was different with the *relative* moistness of the air, namely, the ratio in it of the actual quantity of water present to the maximum quantity which *could* be present in the given volume at the given temperature. This ratio (which alone came into consideration, sanitarily speaking) did get less as the temperature rose; and consequently Dr. Adams, who in his stove made provision for moistening the hot air furnished by it, was right; in principle at any rate.

Dr. ADAMS, in reply, said—The atmosphere was sometimes too dry and sometimes too moist to be wholesome. The water gutter, which formed part of the stove, was a provision through which individuals could suit their peculiarities of sensation, and at the same time it supplied to the physician a desideratum in the treatment of certain chest and throat diseases, and as such it had been cordially approved by the various eminent medical men who had considered and given counsel on this point. If, therefore, it was not necessary, nor an advantage from Dr. Wallace's point of view, it was at any rate no drawback, seeing that it could be used or not used at pleasure. With regard to Professor's Dittmar's opinion that rather too much heat was allowed to pass up the chimney, he might mention that this point had formed the subject of a special investigation by the late Dr. Ure, at the instance of Government. Certain Government officials, whose duties were performed in rooms heated by slow combustion stoves, suffered from ill health. Dr. Ure proved, that owing to the low temperature at which the products of combustion passed into the chimney, there was a want of ascensional force and that regurgitation of carbonic acid and carbonic oxide into the apartments took place. Setting aside the steam vapour, there was the carbonic acid, which was half again as heavy as air, and could not ascend unless greatly heated. Dr. Ure had therefore caused these stoves to be discarded as "poison vomiting coffers," and he recommended 300° F. as a proper and almost necessary temperature, wherever stoves were employed. He, Dr. Adams, had found practically that 240° was a sufficient mean temperature, and did not incline to go below that heat. With regard to the mode he had suggested for estimating units of heat in connection with gas stoves, he thought he had sufficiently explained that the method was only recommended as a rough-and-ready one, never designed to supplant the more elaborate and accurate scientific formulæ, but as an easy and nearly accurate mode accessible to individuals to whom scientific tables and formulæ were as a sealed book. Mr. Hay did not approve of the air entering the stove from a high stratum of the apartment, nor of it being led through any tortuous channel, and yet in both arrangements there was effected an improvement. In the report of the Commissioners appointed by the House of Commons to inquire into the best practical method of warming and ventilating dwelling-houses, the necessity is specially dwelt upon of keeping the floor of a room at a comparatively high temperature in order that the feet may not be constantly in a cold air bath, such as must necessarily be the case in our present chance arrangements for supplying air to a fire from the floor level; and this was the view held by all sanitary authorities, although the customary arrangements of dwellings stood in the way. His (Dr. Adams') method completely met the views of the Government Commission, and of the best principles of Hygiene. Besides preventing cold foot-bath currents of air, the arrangement in question ensured a supply of air for combustion which was free from the dust common to the low floor level, and thus the gas burners were not liable to be choked up, nor the walls of the flue, or of the stove, liable to be coated with impurities that in several ways hindered the efficient action of the stove. The tortuous channels for admitting pure air were in part necessary for the advantageous objects just specified, and in part were also designed to delay the current of air by causing it to pass over a surface of greater length, and thereby to enable it to get better heated. Mr. Buchan, in contrasting the cost of coal with that of gaseous fuel, had not taken into account that the mere first money cost of fuel was not the sum and end of the considerations that would determine every person's choice. There was the ready convenience of the gas, the absence of dust and dirt attendant on the use of coal, the saving of labour in lighting, and in the necessary watchful trimming attendance upon a coal fire. There was the consideration that it is not necessary to keep a gas stove burning continuously, or at its full power. On the contrary, it can be used for short intervals of the day as required, and regulated as to the time it is burned, the intensity of the heating force, or the steady maintenance of the heat it imparts, as easily as an ordinary jet of gas is controlled for illuminating purposes. From such points of view it would oftentimes be found that in the use of gaseous fuel there may be the truest economy.

XIII.—*On the Heating Power of Coal Gas of Different Qualities.*

By Dr. W. Wallace, Gas Examiner for the City of Glasgow.

[Read before the Society, December 3rd, 1879.]

The extensive employment of coal gas for heating purposes, and especially for cooking, gives an interest to the question whether the heating power varies like the illuminating power, and if so, to what extent, in the gas used in different towns? As regards illuminating power, we know that it varies exceedingly. In Aberdeen and Edinburgh it is 30 candles for 5 cubic feet per hour; in Glasgow, Paisley, and Greenock, about 26 or 27 candles; in Liverpool, Manchester, and Carlisle, about 20; in London and Dublin, 16; in Birmingham and many other English towns, 14; and in some as low as 12 candles. But as regards heating power we have no definite information, although there is a general belief that a rich gas has a greater calorific effect than one of poorer photogenic quality.

My attention having been directed to the subject by a correspondent, I caused a small apparatus to be made, in order, when opportunity offered, to test the matter practically. It is of very simple construction, consisting of a cylindrical tin-plate vessel 8 inches in diameter and 6 inches high, with a cylindrical opening in the centre 1½ inches in diameter, through which the whole of the products of combustion pass. It contains exactly one gallon of water. Below is a brass tube bent into a circle 5 inches in diameter, and pierced with 34 small holes, from which the gas burns with flames about ¾ of an inch high. This tube is placed 1 inch from the bottom of the vessel, and is surrounded by an outer case having a sufficient number of small holes for the admission of air. On the top of the vessel there are two openings, in one of which a delicate thermometer is placed, while the other is provided with an open glass tube.

The opportunity of using the apparatus occurred recently, when I had occasion to test, on the same day, three samples of coal, which gave gas of 33, 26, and 15 candle power respectively. Each experiment occupied, as nearly as possible, 30 minutes, and consisted in raising one gallon of water from 60° to 160° Fahr., and measuring the quantity of gas consumed in the operation. The system is by no means a perfect one, but the results are strictly comparative. These are arranged in the following table:—

Illuminating Power of Gas in Standard Candles.	Durability of 1 C. Foot by flame 5 inches high.		Specific Gravity Air=1000.	Comparative value for Lighting.	Gas consumed in Heating Experiment.	Heat Units Fahr. for 1 C. Foot.	Comparative value for Heating.
	Min.	Sec.			Cubic Feet.		
33·07	64	45	574	4/10	1·916	522	4/5
26·24	54	40	525	3/10	2·200	455	3/10
14·75	39	35	442	2/2	2·888	347	2/11½

The heat units represent the number of pounds of water heated one degree Fahr. by the combustion of one cubic foot of gas. I have taken Glasgow gas of 26 candles at 3s. 10d. per 1000 cubic feet as the standard of value, and it will be seen at a glance that, while the heating value rises and falls with the lighting value, the amount of difference is by no means so great in the former as in the latter.

Having made these simple but instructive experiments, I naturally wished to compare the results with the theoretical heating values obtained by calculation from the composition of the gases. Unfortunately, I had no apparatus at the gas-works where these experiments were made for analysing the gases, and the best I have been able to do is to make the calculations from two analyses by the late Dr. Letheby, one of 12 candle gas, and the other of London Cannel gas, the illuminating power of which is not stated, but which may be assumed to be somewhere between 22 and 23 candles. The analyses are given only, as is usual with gaseous mixtures, by volume, but I have, for convenience, calculated the composition by weight.

	Common Gas. 12 Candles. Vol.	Common Gas. 12 Candles. Wt.	Cannel Gas. 22 Candles. Vol.	Cannel Gas. 22 Candles. Wt.
Olefiant Gas, &c., C_2H_4,	3·8	9·5	13·0	24·9
Marsh Gas, CH_4,	39·5	56·5	50·0	54·8
Hydrogen,	46·0	8·2	27·7	3·8
Carbonic Oxide,	7·5	18·7	6·8	13·0
Carbonic Anhydride,	·6	2·4	·1	·3
Nitrogen,	·6	1·5	·4	·8
Aqueous Vapour,	2·0	3·2	2·0	2·4
	100	100	100	100

Specific Gravity (calculated),	387	506
Weight of a Cubic Foot in pounds,	·0296	·0387
Calorific Power, centigrade,	11,790	11,754
Do. do. Fahr., pounds of water heated 1 deg. by the combustion of 1 pound of the Gas,	21,222	21,157
Heat Units for 1 Cubic Foot, centigrade,	345	455
Do. do. do. Fahrenheit,	621	819
Pounds of boiling water evaporated by 1000 cubic feet of Gas,	639	842

We see from this tabular statement that, while the heating power of the two gases is almost identical, weight for weight, the practical result when we take the same measure of gas is very different, the Cannel being much heavier than the common gas. I calculate that in my practical comparative test I have realised about 55 per cent. of the theoretical heating power, which is pretty nearly the proportion of effective heat obtained by the combustion of coal in a fairly well-constructed steam boiler.

The question naturally suggests itself, What is the comparative cost of heating by gas and coal? The calculation is a simple one.

The theoretical heating power of ordinary soft coal may be taken at 13, that is, the number of pounds of boiling water evaporated by 1 lb., equal to 29,120 lbs. for a ton of coal, value say 11s. 6d., being the price of 3000 cubic feet of Cannel gas, the heating power of which is, say 2500. The gas, therefore, costs 11½ times as much as the equivalent quantity of coal, or, in round numbers, a pennyworth of coal gives as much heat as a shilling's worth of gas. When, however, we consider the handiness, the cleanliness and the convenience of gas, it is not surprising that it is extensively employed as a source of heat, as an illustration of which I may state that in my own laboratory from 250,000 to 300,000 cubic feet are consumed annually, almost the whole of which is burned for the production of heat.

XIV.—*The Ventilation of the Rooms of Houses, with Experiments.* By HORATIO K. BROMHEAD, A.R.I.B.A.

[Read before the Society, March 31st, 1880.]

THE object of this paper is to consider the ventilation of an ordinary house room.

Ventilation is a difficult study to those who know all about it before they begin to give the subject any attention. The student who is not prepared to throw aside popular prejudice must meet with disappointment and be much disheartened.

It is possible to get good dictionary authority for the statement, that to "ventilate" is to fan with wind! or to open and expose to the free passage of air! If the question is studied in some new public halls and other buildings, the painful conclusion is forced upon one that to ventilate is to blow cold air on people's heads and feet—sometimes one, sometimes the other, and more often both!

That is not what is wanted. When a field or house or other place is *drained*, the word does not imply that clean water is poured into or upon it. The condition described is this, that certain pipes or apertures have been made with accuracy, experience, and skill, in accordance with the need for them, and so that the impure or obstructing liquid can escape at once, and cannot remain and accumulate.

The word "vent" means to let out at a small aperture, to suffer to escape, or to pour forth. When a room is "ventilated," the word does not (or ought not to) mean that fresh air is poured into or upon it. A ventilated room should be so constructed that impure air can escape at once, and cannot remain and accumulate within it.

There are two arguments about this—the one theoretical, and the other mechanical. The theoretical argument is this:—A room that is in want of more ventilation is in want of more air, or in want of fresh air. Now that theory is quite wrong from a mechanical point of view. A room in want of ventilation is not in want of air, for it is quite full. It is not, properly speaking, in want of fresh air. To bring out the meaning of this, the following proposition is formulated:—

When tainted air goes out of a room, it must be replaced by the pure air surrounding the room.

But that proposition cannot be reversed. When pure air goes into a room, its tainted air *might* go out; but that is not a necessity, and is not at all likely. In ordinary rooms, the probability is that the pure air will go out at some other opening as fast as it comes in, and still leave impure air in the room. Of course the relative lightness and ascending capacity of impure air is the cause of its accumulating at the ceiling, and remaining there, even though better air is going in and out of the room.

The mechanical argument amounts to this, that the ordinary construction of a room permits the free admission of fresh air, but does not offer facilities for the removal of tainted air. It therefore leads to the further statement, that ventilation ought not to be a system for giving more fresh air, but one for leaving as little as possible of tainted air in a room.

If a common tea-pot be placed so that the mouth of its spout is a little below the top of the tea-pot, and then filled with water, and the top of the water covered with anything like oil that will float on water, then a continuous stream of water may be poured in at the top, through the oil, and caused to flow out at the spout, but the oil will float and remain. On the contrary, if the mouth of the spout is raised so that it is higher than the top aperture of the tea-pot, then the water can be poured into the spout so as to cause the oil to overflow. The oil can be so removed by pouring in very little more water than the bulk of the oil. A vessel having two spouts like a tea-pot, can be filled with water covered with oil, and then a stream of water can be poured into one spout so as to overflow at the other, but such a stream will never carry out the oil with it. This is an accurate illustration of the ventilation of a great many rooms. Nearly all fires have a chimney full of air passing away from them at the rate of more than 100 feet* per minute. With that amount, if the door of the room is left open less than 2 in., air enters near the floor at the speed of 100 feet per minute, gradually changing to 50 feet per minute above the head. Now, such a room becomes very impure when occupied for a time by a number of people, and it becomes particularly bad when the gas is lit. The much greater degree of sensitiveness that is evinced against the bad air of a room where gas is burning, is possibly due to the alien and somewhat poisonous nature of the products of gas combustion as compared with exhaled air, which, having come from the lungs, is naturally not specifically irritative to it, although it may be just as bad, and useless to the lungs. The amount of air passing through such a room is more than 50 cubic feet per minute, and as the ordinary exhalation of the lungs is about 12 per minute—each being very much less than a cubic foot—it follows that the quantity of ventilation is sufficient for a fair number of people with gas also. But where there is no special ventilation the middle level of the room does not maintain a reasonable purity of air, and the upper part is simply abominable.

The circumstances of the room are these:—There may be two windows and a door, having about 80 feet of narrow cracks all admitting air at a considerable speed. These deliver the 50 or more cubic feet per minute.

A kitchen close range, or an ordinary furnace, give the high velocity of more than 1000 feet per minute, and ordinary unassisted chimneys, without a fire, generally have a velocity of nearly 50 feet per minute. An ordinary fire is therefore fully twice the speed of the chimney from an unused fire.

Now, every one knows that the atmosphere of the upper part of a room is very much worse than the middle. The air nearest the floor is correspondingly the best, and when this is taken into consideration, in connection with the varied or dispersed positions of the cracks that supply air to the room, they furnish no explanation; because they spread their supply, and yet are powerless to diffuse the fresh air.

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* Lineal feet are always meant, unless otherwise stated.

When, however, the differing state of the air in the different levels of a room is considered in connection with the one egress for air, the fire-place, at the bottom of the room, 2 feet from the floor, and in connection with the tendency of impure air to ascend, it is impossible not to be struck with the unfailing manner in which the effect in every case follows the cause.

It is now forced upon us to inquire why poor mortals, who are perpetually crying out for more air, should be so absurd as to construct their rooms air-tight at the top, in a manner that prevents any serious approach to ventilation? There is no difficulty about the answer. Ventilation is generally left to chance, or to "practical" men, as they are called. That magic word conjures up unlimited faith, almost as readily as the German uniform sets off a brass band. They may come and annoy one night after night with the most hideous out-of-tune noises, one man at the melody and all the rest begging, save the one who remains playing one note of the accompaniment violently out of tune. Whether they are really German, or only sham, does not affect the quality. My impression is that some of the shams play as badly as the real German musical tramp, or at least as near that as is possible. Of what use would it be to ask them to play in tune, and to play the accompaniments only to the tune to which they belong. The only answer obtainable is a shrug, a smile of indifference to anything but money, and the production of a cap after a peculiarly clumsy and expressive fumble with the brass instrument. Now, this really is not so much a digression as it might appear, for there is an enormous quantity of the brass band about the "practical" man. Of course it is not stated that the little practical man exists in every walk of life. When one gets a bad attack of gout, or a broken leg, then the dealers in port wine, and the manufacturers or sellers of chemicals or surgical instruments, are not sent for and employed.

But in ventilation it is quite different. That is rather a long, grand name; but, ironically, it may be understood to mean holes and cold wind. Those who can really face this meaning, send for the very nearest small mason, or brickbuilder, or carpenter, or plasterer, or plumber, or gasfitter, or ironmonger. All the small ones are practical men. The very dictionary helps to express the matter so. It says that practical is "not *merely* theoretical," and also that theoretical is "speculative," and "not practical." So, in our school days, we learn that the practical man—besides having an imaginary unspeakable inborn experience that, according to the dictionary, is not the companion of mental training, and that is not expected in a properly trained individual,--has also *mere* theory in a subsidiary manner, which is, of course, all that such a man needs. When you meet the real small-practical-man he is a treat. His time has often been saved from unnecessary education. Why need he know rules and figures? He can look at a case and say what it wants without calculation or scientific reason. Indeed, a large small-practical-man has men in his employ that can come and look at your room, and at once, without any waste of time, point out where to make a hole, and the size required. If the hole fails, that is not his blame, for his theory is not wrong, because he has no mere theory. It is a practical hole of the stipulated size, and it is there as his practical sagacity foreknew that it could be. Mere theory could not have known that in this particular case it would not be satisfactory, because he, both practical and mere-theoretical, did not and cannot prophesy every freak of so changeable an affair as the wind. Had he designed the building it would have been different. But now there he is, practical. He can shut it up and make another, both in the most practical way, and let in wind in some new place.

So we come upon the very distinct information that the bad result of many failures is too much wind. There is many a room wanting ventilation, and yet already endowed with too much wind. It will certainly be said that this is dreadful platitude. So it is, when it is not understood! Let it therefore be translated, and we shall say that what is wanted is ventilation without wind. Ventilation is, as we have found, composed of two parts—viz., inlet and outlet. Inlet is wind. Outlet is not draught. Then the translation must be completed by saying that what is wanted is better outlet, and not more, but perhaps less inlet.

This brings us up to the date of Dr. Arnott, who seems to have been seeking to make a skilful workable outlet at the top of the room, where the worst air is.

Many people get the length of saying they must have a hole up from the ceiling, and they make it large enough to act against the draught of the fire-place; and so the fire inclines to smoke when it is lit, and the vent gets a tendency to blow down when the fire is not lit. The doctor got beyond that difficulty when he made the hole into the vent. Here, however, he met with another difficulty which he never seems to have understood, or have been able to overcome. The smoke of the vent came out into the room.

It really was wonderful how people persevered with these openings, even although they had to be formed under the illogical difficulty of having a Dr. Arnott's valve, so as to prevent the tendency of the opening to positively work backwards, and do the very reverse of what was wanted.

Next we should inquire, why Dr. Arnott's valves do not act, or, more particularly, why is a valve necessary, and why does the opening so often work backwards, and bring the burnt air, and gas, and soot, from the vent into the room? The explanation is very easy, and is fatal to Dr. Arnott's valves. A vent in action is a column of heated air reaching from the fire to the chimney can, and heat is its normal power of ascension. This heat is not equal, but is greater at the bottom, and the ascending power must therefore be greater at the bottom; the lower part of the heated air must therefore be pressing up after the other, and a slight expansive pressure must occur upon the sides of the vent, enough to drive smoke through openings, the more so when the chimney can at the top is smaller than the vent.

Then we have science, in the person of Professor Pepper, advancing the matter. He points out that there is an induced current of air round the fire-place, and that if a pipe is led from it to the ceiling, it would draw down the most impure air from the ceiling, and deliver it into the vent, which would carry it away. But then the Professor was not a "practical" man in the eye of the dictionary. His was a mere theory, so it did not receive universal attention. A great many years have gone by, and several "practical men" over the country are beginning to get it into their heads, and partly understand it, and claim it as their own, and patent it.

In its most advanced form it consists of one or more tubes that commence near the ceiling, and are brought down to a position behind the grate, to where it is ascertained that a perpetual inducing current exists, and to such a level as to be below the aperture where the smoke of the fire-place passes through the grate into the vent. (It is always *possible* for it to work well if it is placed a little higher than that level, but it is very rarely free from occasional back-smoke when the opening is above the aperture of the grate.) The flame of a wax match or candle, when held near the

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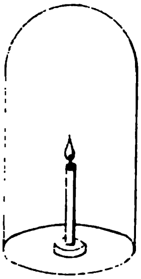

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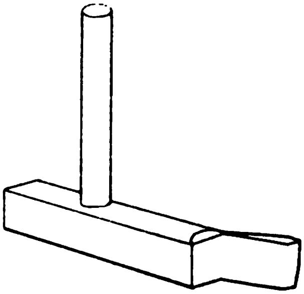

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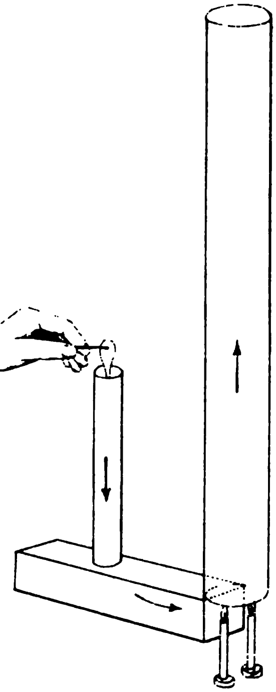

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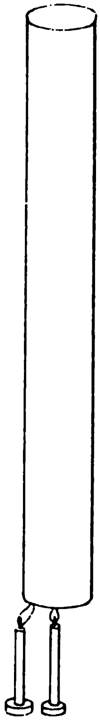

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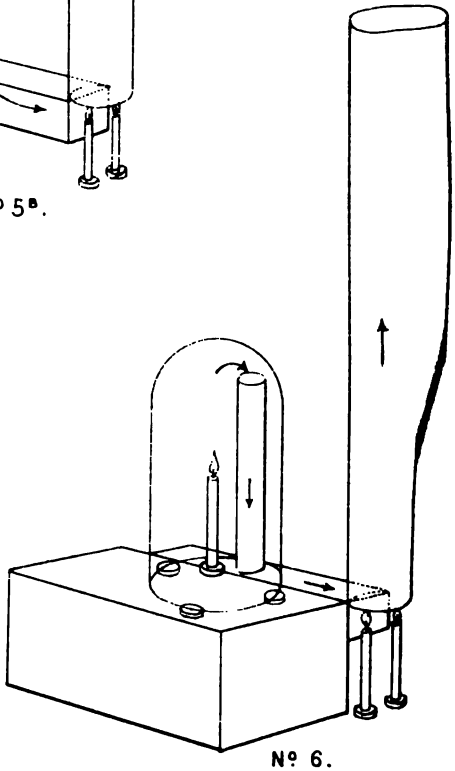

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EXPERIMENTS.

various parts of a grate, will indicate where the inducing current is; and if the grate is loose, and can be brought out half-an-inch, that aperture all round will act on the candle, and show the induced current that exists behind it.

A few simple experiments beautifully illustrate this:—

1*st Experiment.*—Take small wax candles, ½-inch diameter, light one, and place it with the top of its wax 7 inches above the table, and place over it a glass shade, 8 inches diameter and 14 inches high, and the candle will deposit a great deal of moisture on the glass, and go out in about 2¼ minutes.

2*nd Experiment.*—Repeat the experiment with the glass shade raised on a penny-piece at three different places, and the candle will still go out in about 2¼ minutes. Therefore, there is no ventilation, although, as Experiment No. 6 will prove, there is plenty of aperture for admitting enough air to supply the candle.

3*rd Experiment.*—Repeat the last experiment with an additional candle only 1½ inch high. The upper one will go out in 1¼ minutes, and the lower one in 1½ or 1¾ minutes. This is further proof that the contamination and accumulation commence above.

4*th Experiment—the Induced Current.*—Form a small chimney, say 4 inches diameter and 3 feet long (it may be made of paper glued together). Fix it up vertically, and place a lighted candle below it, and the vitiated air will issue at the top at a speed of 120 feet per minute. Place a second candle under it, with its wax about 1¼ inch below the paper tube, and gradually bring this second candle out till it is not standing under the chimney, but just outside it (speaking vertically). The inducing current will now be found to draw the flame into the chimney without burning the paper of the chimney. The two candles give a velocity of 170 feet per minute.

5*th Experiment.*—(A) Form a ventilator, consisting of a 1½ inch diameter tube, 12 inches long, and insert it into an air-tight cardboard box, 2 or 3 inches square by 12 inches long. Place it 4 inches from one end, and form a half-moon opening at the top of the farthest end of the box. (B) Place this half-moon opening under the chimney, and put two lighted candles under the chimney. It will now be found that the inducing current has formed a down draught in the ventilator, and a lighted wax match held over the ventilator will burn with the flame drawn downwards by the induced current.

6*th Experiment.*—Combine the chimney and ventilator with the

2nd experiment, putting two lighted candles under the chimney, and delaying to do so until the candle under the glass shade is nearly out. It will now be found that the ventilation commences at the moment the two candles are placed under the chimney, and that the candle under the shade revives almost immediately and burns fully, and that the ventilation is sufficient to rapidly absorb the condensed moisture inside the glass shade. The rapid action of this experiment, if it is properly made, is very brilliant and astonishing. By removing and again adding the two candles, the action of this experiment can be readily repeated for observation.

The first great value of this ventilation consists in the direct immediate removal of impurities as fast as they gather and ascend to the ceiling.

The second value is the absence of draught. The vitiated air is, in going into the chimney, taking the place of the good warm air that the smoke of a fire-place always induces away with it. This being so, there is not only no need for further holes to admit more cold air into the room, but there is also the possibility of shutting up some, when the room has too many, without thereby interfering with the proper necessary ventilation.

The third value is in there being nothing moveable, and nothing to watch and regulate.

There is a marvellously small quantity of power required, for the ventilator works continually, and there never is any accumulation to work off. A pipe 1½ inch diameter for a single bedroom and 2 inches diameter for a double bedroom, is ample, if there is a respectable draught up the chimney when the fire is not lit, as there ought always to be. (This can easily be ascertained by holding a lighted match or candle at the vent.) In ordinary sitting-rooms 2½ to 3 inches diameter is enough for any ordinary occupation, and when a fire is burning, is even enough for 20 people; for there is a great deal of door-opening with 20 people in a room, and that greatly increases the speed of action, which is so great that, when a lighted wax match is placed close to the aperture at the ceiling, the inwards draught will often suck away the flame or blow out the match.

It is not professed that all this is by any means a new discovery, but rather that these principles have been gaining ground, and asserting their power for perhaps 40 years, in spite of violent prejudice.

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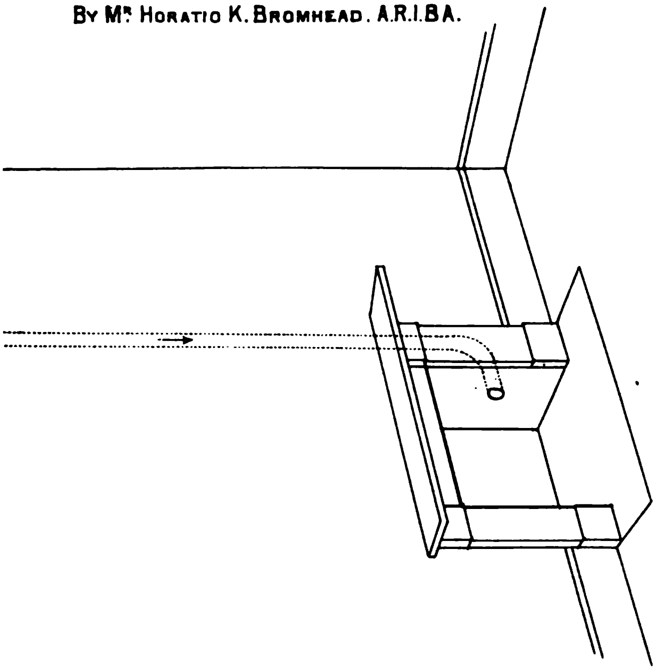
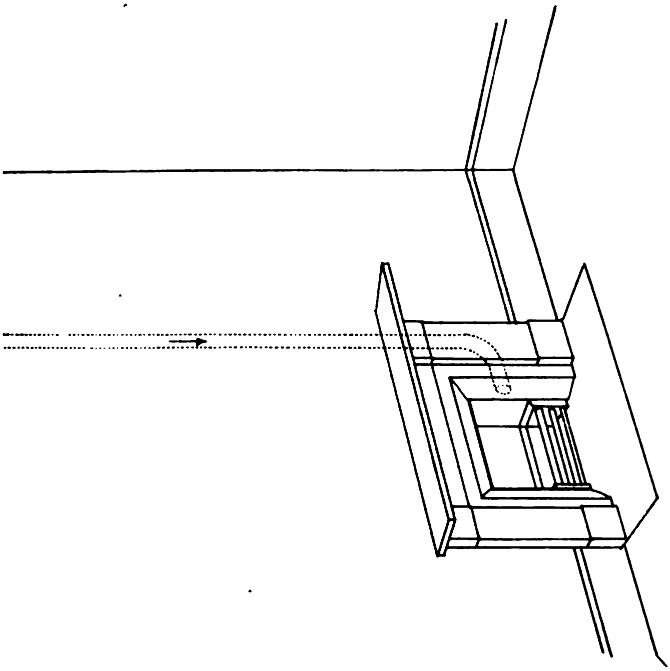


WHEN THE GRATE IS AWAY



THE VENTILATOR

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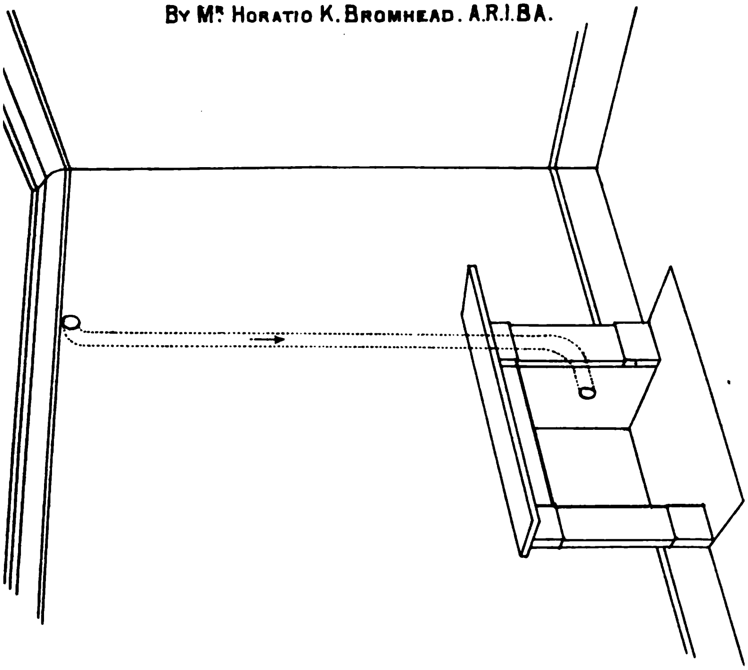

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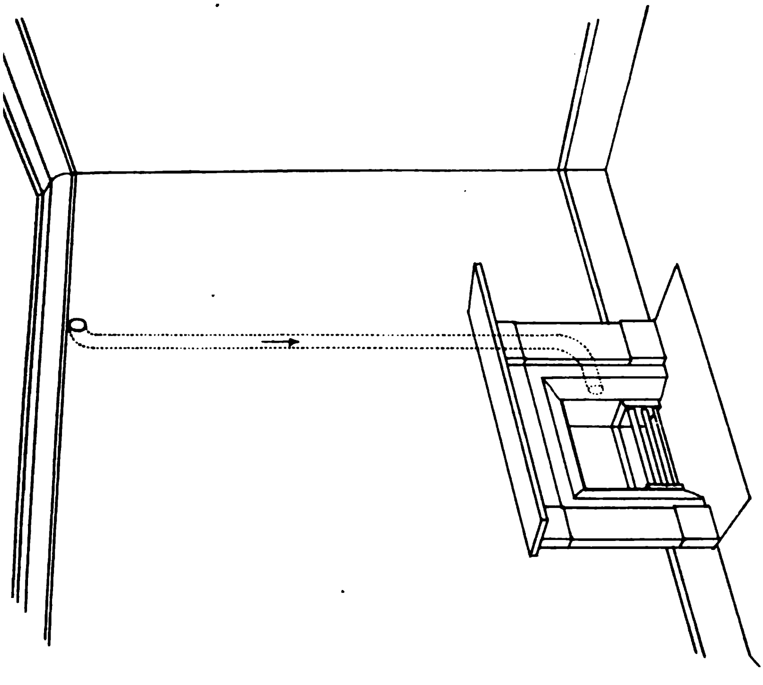

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stupid at ventilation, and I know several cases where very absurd advice has been the cause of unmitigated failure.

It is hoped that this paper and these experiments are so clearly and plainly indicative of the principles involved, that they will enable any one to understand the simplest and cheapest way to ventilate a room.

XV.—*On the Pellets occasionally found in Pig and Foundry Iron.*

By ROBERT R. TATLOCK, F.R.S.E., F.C.S.

[Read before the Chemical Section, April 5th, 1880.]

ABOUT a year ago I was requested to make an analysis and examination of some pellets which had been found embedded in a pig of No. 4 iron, with the object of determining whether there was any difference in composition between them and the iron in which they had been formed, and also of ascertaining, if possible, the cause, with a view to the prevention of their production. A careful analysis of each was made, with the following results :—

	Pig-Iron per cent.	Pellets from preceding. per cent.
Iron, ...	92·42	92·38
Manganese, . .	·79	·90
Carbon (combined), .	·40	1·30
Carbon (graphite), .	2·69	2·20
Silicon, . . .	3·00	1·60
Sulphur, . . .	·12	·08
Phosphorus, . .	·58	1·54
Titanium, . . .	..	...
	100	100

These analyses bring out a striking difference in composition between the two, the pellets showing nearly three times as much phosphorus and of combined carbon as the iron, and only about half the proportion of silicon, while there is a very appreciable difference in the amount of graphite, the pellets containing the lesser quantity. It is but right to say that while the phosphorus, silicon, and sulphur, were determined in the pellets obtained from the identical pig of which the above is the analysis, the other ingredients were estimated in some which were taken, not from the same pig, but from the same brand of iron—made in the same works at the same time. Considering that it would be more satisfactory to have complete analyses of each from the same pig, I obtained, through the kindness of one of the large iron manufacturers near Glasgow, the necessary samples, of which I have just completed the analysis, with the following results:—

	Pig-Iron No. 4, per cent.	Pellets from preceding, per cent.
Iron,	93·59	93·03
Manganese,	·79	·61
Carbon (combined),	·85	1·15
Carbon (graphite),	2·70	1·90
Silicon,	1·13	·81
Sulphur,	·18	·15
Phosphorus,	·67	2·26
Titanium,	·09	·09
	100	100

These results entirely corroborate the previous ones, but more particularly as regards the phosphorus, the proportion of which has increased in the pellets to from three to four times that present in the iron; and the relative composition of the two is thus placed beyond a doubt.

These pellets are not unfrequently found on breaking up the pigs. They occur principally near or at the upper or flat surface, and most frequently, I am informed, in No. 4 iron. The object of examining these samples was partly to ascertain what connection, if any, they had with the hard metallic spots found on the surface of iron castings, and known technically by the name of "shagreen." My attention was first directed to the latter about five years ago, by Mr. Robert M'Alley, Public Analyist for Falkirk, who has paid much attention to the subject, and who then furnished me with the following analyses which he had made of some of these, and of the pig-iron used in making the castings which contained them:—

	Pig-Iron, per cent.	"Shagreen" from preceding, per cent.
Iron, ...	90·00	88·50
Manganese, . .	2·01	1·86
Carbon (combined), .	1·10	2·20
Carbon (graphite), .	2·40	1·00
Silicon, . . .	3·26	2·38
Sulphur, . . .	·04	·02
Phosphorus, . .	1·11	4·00
	99·92	99·96

These analyses, made years before mine, show precisely the the same differences between the "shagreen" spots and the corresponding iron that mine brought out between the pellets and the iron in which they were found embedded, but even more strikingly—the phosphorus being nearly quadrupled, and the combined carbon doubled, while the silicon and graphite were much reduced in proportion. A comparison of all the results seems to render the conclusion unavoidable that the "pellets" and the "shagreen" are produced from the same cause. The latter, when they appear in castings which have to be turned or planed, are a source of great annoyance, and as they appear at the surface of the metal, and are so excessively hard that no file nor tool will touch them, they are generally the means of destroying the entire casting, which must be broken up and re-melted. The ironfounders, however, have found a means of preventing them, which consists in the addition of a greater or less proportion of "scrap" castings—a process which is manifestly equivalent to a re-melting of the iron.

The explanation of the formation of these hard bodies is perhaps difficult, but it is quite clear, from the appearance of the pellets, that they have remained in a state of fusion after the bulk of the iron had practically solidified, and this seems almost a necessity from their composition—phosphide and carbide of iron being more fusible than the purer metal, which solidifies first, leaving these compounds in a fluid state as a mother liquor, from which the comparatively pure iron has just crystallized. This fluid thereafter becomes solid, forming the little spherules or pellets, which are generally found lying quite loose in the cavities which contain them, but sometimes adhering to their walls. In fact, there seems little doubt that they are produced by an action similar to that which occurs in the Pattinson process for the desilverization of lead.

It is long since it was proposed to purify pig-iron by taking advantage of the fact that phosphide and sulphide of iron solidify at a considerably lower temperature than iron which is approximately pure; but in practice, the action is either not sufficiently complete, or the separation is not perfect enough to affect very appreciably the composition of the iron produced. About ten years ago protection was granted to Mr. A. C. Kirk, of this town, for a method of purifying iron in this way. The pig-iron used in the experiments contained about 1·5 per cent. of phosphorus to begin with, and the trials consisted in melting and casting a large quantity of the metal, and lifting off, by means of a crane, successive plates as they solidified. It was expected that the first plate would contain the smallest, and the last the greatest proportion of combined impurities, but about 20 analyses showed that there was scarcely any difference. The theory, however, is undoubtedly correct, and the failure in practice arises simply from the circumstances that the proportion of liquid phosphide and sulphide (or carbide) of iron separated is too small to affect the composition and quality of the remaining iron.

XVI.—*Note on the Composition of a Peculiar Water.*

By Dr. W. Wallace, F.R.S.E., Glasgow.

[Read before the Chemical Section, April 5th, 1880.]

Composition of Water from a bore 100 fathoms (600 feet), near Paisley—Lower carboniferous strata.

	Per 100,000.	Grains per gallon.
Barium Carbonate,	5·41	3·79
Calcium Carbonate,	26·26	18·38
Magnesium Carbonate,	2·30	1·61
Calcium Chloride,	9·24	6·47
Magnesium Chloride,	7·80	5·46
Potassium Chloride,	2·40	1·68
Sodium Chloride,	178·30	124·81
Alumina, &c.,	·80	·56
Silica,	·70	·49
Organic and Volatile Matters,	8·50	5·95
	241·71	169·20

Hardness,	53·7	37·6
Oxygen required to Oxidize Organic Matter,	·167	·117
Ammonia, Free,	·095	·067
,, Organic,	·007	·005
,, Total,	·102	·072

Contained no nitrate nor sulphate.

XVII.—*On the Condition in which Sulphur exists in Coal.*

By Dr. W. WALLACE, F.R.S.E., GLASGOW.

[Read before the Chemical Section, April 5th, 1880.]

IT has been assumed that sulphur exists in coal chiefly, if not exclusively, in the form of bisulphide of iron, the presence of which can be detected in almost all varieties of the mineral. Crace-Calvert asserted, many years ago, that, in some cases at least, sulphur existed in coal in the form of a sulphate, and he gave a process for the estimation of the sulphur existing in this form. Some analyses which I have recently made have shown conclusively, however, that in some coals the greater part of the sulphur exists as an organic compound. These coals contain but a small proportion of iron—not nearly enough to form bisulphide with the iron that exists in them; and one well-known description, known as the Ell coal, was found not to contain a trace of sulphuric acid when tested by Crace-Calvert's method. The others were not tested.

The following table shows the relative quantities of total sulphur, and that existing as pyrites, as calculated from the iron found in the ash of the coal, assuming that all the iron exists as bisulphide, which is not always the case, as some coals contain carbonate of iron:—

	Total Sulphur.	S. as bisulphide.
Ell Coal, Lanarkshire,	·91	·11
Main Coal,	·60	·42
Splint,	·46	·14
Pyotshaw,	·68	·17
Soft Coal from Fife,	·93	·49

The estimations of sulphur were made by [illegible]'s method, and also by fusion with sodic carbonate and potassic nitrate. When carefully performed, and check experiments made to eradicate sources of error, these methods give concordant results. It is well known that boiling with nitric acid does not give the whole of the sulphur, and I find that the amount obtained usually corresponds closely with that existing as pyrites.

The following analyses of the coals referred to may be useful for comparison with English varieties, of which the composition is given in several works on chemical technology.—

	Ell.	Main.	Splint.	Pyotshaw	Fife.
Carbon	[illegible]	[illegible]	70·85	72·21	61·88
Hydrogen	[illegible]	[illegible]	5·24	4·79	4·89
Oxygen	[illegible]	12·[illegible]	12·97	9·77	12·78
Nitrogen	1·44	1·40	1·36	1·51	1·14
Sulphur	·91	·80	·85	·68	·93
Ash	·91	1·80	3·80	2·74	3·92
Water at 100° C.	11·36	3·36	4·72	8·30	14·46
	100	100	100	100	100
Specific gravity	1·253	1·283	1·282	1·280	1·250
Heat units, Cent.	7130	6628	6929	7062	6132
Do. in Fahr.	12,842	11,932	12,472	12,711	11,037
Pounds of Water evaporated by 1 lb. of coal (theoretical).	13·20	12·15	12·74	13·00	11·21

In calculating the last figure, allowance has been made for the evaporation of the water contained in the coal. Some authorities give the results of analyses of coal in the dried state, but such statements are of little practical value, and are apt to mislead consumers of fuel. The water in coal, although readily expelled by heat, varies very little in samples taken from the pit at different times, and, in fact, is as constant as the composition of the coal itself, which varies sensibly in different portions of the field.

XVIII.—*Contributions to our Knowledge of the Rugose Corals, from the Carboniferous Limestone of Scotland.* By JAMES THOMSON, F.G.S., Corresponding Member of the Royal Society of Sciences of Liège, and Honorary Member of the Royal Ducal Society of Jena.

[Read before the Society, April 14th, 1880.]

THE following paper contains a description of several genera and species of corals from the carboniferous rocks of Scotland. Some of them have been known to me since the year 1866, and although long since satisfied that they were new and undescribed groups, I have delayed introducing them into our palæontological lists until I had accumulated a large series of specimens; and, before finally deciding either genera or species, had submitted them to some of our ablest palæontologists, both British and Foreign, and more especially to my friend, Mr. Robert Etheridge, Senr., F.R.S., &c., President of the Geological Society of London,* who kindly examined them, along with a considerable number of other genera and species, some of which have already been recorded in the *Proceedings of the Philosophical Society of Glasgow,* and others of which are yet to be considered. My own conclusions being in this way confirmed, I now submit them to the scientific public.

The specimen which is delineated in Plate II., Figs. 1, 1A, 1B, and 1C, is seven inches long. Fig. 1 represents the calice, which is imperfect; Fig. 1A is a transverse section taken an inch and a half below the superior extremity of the corallum; Fig. 1B is a longitudinal section three inches from the crown of the corallum; and Fig. 1c represents a transverse section one inch from the inferior extremity of the corallum. This I felt the desirability of doing in order to show that the structural characters are continuous from the superior to the inferior extremities of the corallum.

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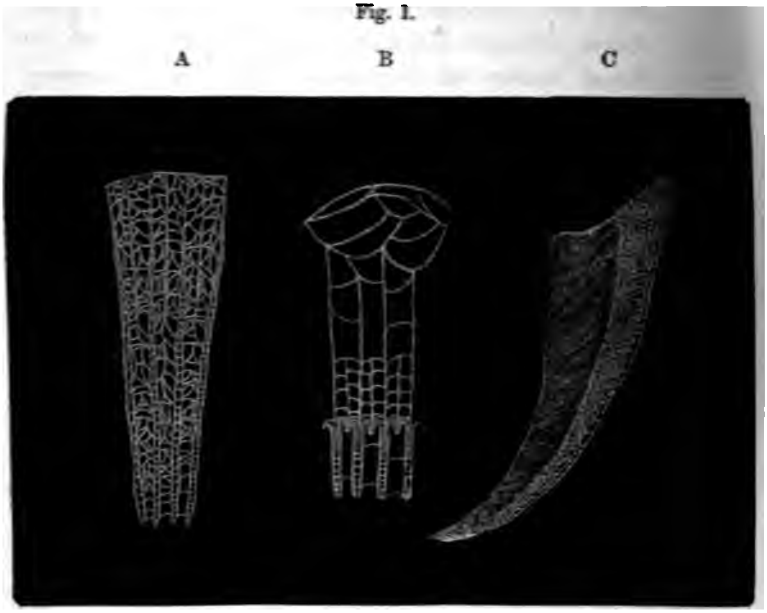
* To whom I beg to offer my cordial thanks for thus kindly giving me the benefit of his large experience, and so aiding me in the classification of this group.

Fig. 1.

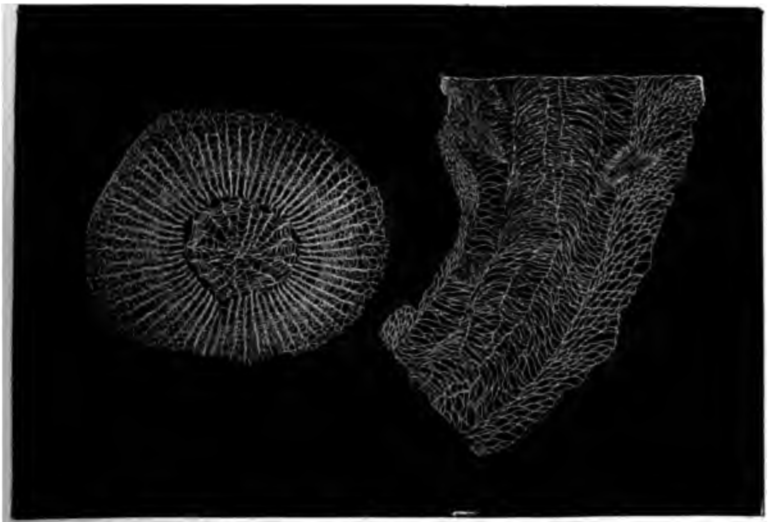


From the subjoined generic diagnosis it will be seen that I describe here for the first time a system of transverse plates that are found in the interlamellar portion of each septum (Fig. 1A), which plates, in a longitudinal section, are seen passing inwards and downwards along the inner faces of the lamellæ that form the lateral walls of the bilamellar portion of the septa (Fig. 1c)—a discovery which I made recently in microscopic sections which I prepared for the investigation of another important physiological point in the structure of rugose corals, and regarding which I hope to be able to give details by-and-by. Reference is also made to the bilamellar structure of the septa, lamellæ, and interseptal dissepiments. These I also discovered during the above microscopical investigation.

Fig. 2.

Genus centrephyllum. *Thomson.* Gen. nov.

A B



Generic Characters.—Corallum simple, cylindrical and conical near the inferior extremity, and cornute. They are tall in the cylindrical forms, while in the others they are variable; epitheca thin, with minute crenulate encircling lines, and irregular annulations of growth; calice circular and moderately deep, and in some forms everted, exhibiting in the centre of its floor a slightly elevated boss, which is formed by a series of ridges of variable number, and which are the free ends of the lamellæ of the central area converging inwards and upwards from the inner margins of the primary septa to the centre of the calice. The septa are variable in number and stoutness, and are of two orders. The primary never extend further inwards than to the base or outer margin of the elevated boss in the central area, and exhibit laminæ for about three-fourths of their length from their inner margins, while towards the periphery they are single, thin, and more or less flexuous. The interlamellar area is occupied by minute transverse granular plates, in number from four to twenty-two in the space of a line, which in a longitudinal section are seen to pass inwards and downwards along the inner face of the laminæ (Fig. 1c). The secondary septa are minute and hardly recognisable in the vesicular tissue that surrounds the outer zone; they are united by interseptal dissepiments, which are few in number near the inner margins of the primary septa, and more or less numerous in the external area, where they form a dense vesicular tissue. The walls of the septa, the lamellæ, and the interseptal tissue consist of two layers—the inner, dense and granular; the outer, also granular, but much less dense. The fossula is variable in size in the different varieties, but usually well marked.

The longitudinal section (Fig. 2B) is triareal. The middle of the central area is composed of thin discontinuous columellarian lines, and each of these lines is united by concave tabulæ, while at the outer margin of the central area they are convex, the convexity pointing upwards and outwards. The intermediate ("interlocular") area is composed of convex tabulæ, convexity upwards, these tabulæ uniting the inner ends of the primary septa.

The outer ("interseptal") area is occupied by more or less irregular lenticular convex cells, convexity pointing upwards and inwards, and arranged in oblique rows.

The group which forms the subject of the present communication has had my attention since 1866. In the autumn of that year, I discovered in Thirdpart, near Beith, Ayrshire (Pl. I., Figs. 2, 2A, 2B), the first form, which struck me as being different from any of the genera or species that had previously come under my observation, and which certainly is not recorded in the valuable memoir of M. Edwards and J. Haime, published in the *Transactions* of the Palæontological Society in 1850. Since then I have frequently visited that and other localities, and I have accumulated a sufficient data to warrant me in creating a new genus for their reception. I have in my own cabinet upwards of forty well-marked varieties; meanwhile it is only those forms that are most strikingly pronounced which I have selected for specific distinction.

In the general features of the external aspect the forms which I have grouped under the name of Centrephyllum present a close resemblance to those which properly belong to Clisiophyllum (Pl. I., Fig. 6), but they are nevertheless separated by characters sufficiently distinct to warrant their being placed in a group by themselves. The generic characters of Centrephyllum agree with those of Clisiophyllum in the triareal arrangement of their structure, as shown in longitudinal sections.

In both genera the outer area consists of convex vesicles arranged in oblique rows, the convexity pointing upwards and inwards. In both genera the intermediate area is occupied by convex and sparse tabulæ, the central area, which is formed by vasicular tabulæ, is more or less elevated centrally, and the calicinal boss is somewhat conical. In both genera also primary and secondary septa are developed. The primary septa extend from the periphery to the outer margin of the central area, and all exhibit well-developed laminæ; also the interlamellar area is occupied by minute rectangular plates—the septa towards their outer margin becoming delicate and single.

With these points of resemblance there are the following points of difference to be noted in the structural characters of Centrephyllum and Clisiophyllum respectively.

(1) In Centrephyllum the lamellæ are seen in transverse sections to converge, and a portion of them meet in the centre of the calicular fossa (Plate I., Fig. 1). In Clisiophyllum the lamellæ do not coalesce in the centre, but converge to the median rod, which extends from the inferior to the superior extremity of the corallum. Also the cut ends of the lamellæ are much less regular in the former than they are in the latter (Plate I., Fig. 6).

(2) In longitudinal sections of Clisiophyllum there is a continuous central median rod, and the vesicular tissue on either side of the columellarian rod is convex—convexity upwards and outwards; while in Centrephyllum, in the central area there are several vertical plates, and these are united by concave tabulæ.

(3) In Clisiophyllum the boss in the centre of the calicular fossa is conical and broad, and surrounded by the free ends of the vertical lamellæ of the central area. These converge to the columellarian rod in the crown of the conical boss. In Centrephyllum the boss in the centre of the calicular fossa is less conical, and the free ends of the vertical lamellæ converge and meet in the centre of the central area (Plate I., Fig. 1).

(4) The tabulæ in the central area in Clisiophyllum are convex, the convexity directed upwards and outwards. The reverse of this condition is the case in Centrephyllum—the tabulæ being concave.

(5) The secondary septa are much less developed in the latter—indeed, they are often hardly recognisable in the vesicular tissue of the outer area (Plate I., Fig. 5). In Clisiophyllum the secondary septa usually extend inwards from the periphery to near the interlocular area (Plate I., Fig. 6).

It will thus be seen that the above marked characters of the central area are sufficiently distinct to warrant the establishment of the group into a distinct genus, as I am persuaded that it is only in the structure of the central area that there is any classificatory value for either generic or specific distinction.

Centrephyllum subcentricum. *Thomson.* Sp. nov.

Plate I., Figs. 1, 1A.

Specific Characters.—Corallum simple, moderately tall, conical and curved, calice imperfect, epitheca thin, with fine encircling striæ and broad shallow annulations of growth. The septa are moderately stout, and bilamellar for three-fourths of their length from the inner ends. There are twelve interlamellar rectangular plates in the space of a line, which are the cut ends of the interlamellar striae and are seen in the longitudinal section. The septa are single and flexuous in the outer area. There are sixty primary, alternating with an equal number of short secondary septa. The latter are hardly recognisable in the interseptal tissue which they intersect. The central area is circular, and is six lines in diameter, and in transverse section exposes the cut ends of seventeen vertical lamellæ. Five of the lamellæ converge and meet subcentrally on the dorsal side of the corallum.

The longitudinal section is triareal (Plate I., Fig. 1A). In the central area there are a few thin discontinuous columellarian lines, and in the centre these are united together by concave tabulæ, which are somewhat distant from one another; whilst towards the outer margins the tabulæ are convex, convexity pointing upwards and outwards.

The intermediate ("interlocular") area is occupied by more or less convex tabulæ. The outer ("interseptal") area is broad, and occupied by convex tabulæ, convexity pointing upwards and inwards, and arranged in oblique rows. The fossula is moderately large, and two of the primary septa, shorter than the rest, pass into it.

Height of corallum, three inches. There is a small portion of the inferior extremity wanting, probably about three-quarters of an inch. Diameter of section, one inch seven lines.

Formation and Locality.—Found in a band of shale near the base of the marine beds of the carboniferous system at Thirdpart Quarry, near Beith, Ayrshire.

This species is distinguished from the other species of the genus by the central area, which is greatly less in proportion to its breadth, and the lamellæ are more numerous than in its nearest allies.

Centrephyllum bicentricum. *Thomson.* Sp. nov.

Plate I., Figs. 2, 2A, and 2B.

Specific Characters.—Corallum simple, moderately tall, conical, and curved, epitheca thin, with crenulating stria and broad annulations of growth. The calice is circular and moderately deep, and in the centre of its floor there is a broad and slightly elevated conical boss. The septa are lamellar for three-fourths of their length from the inner ends, and there are eighteen interlamellar rectangular plates in the space of a line, which are the cut ends of the interlamellar striæ, which are exposed in several parts of the longitudinal section (Pl. I., Figs. 1A and 2B). The septa are more or less flexuous towards the periphery. There are sixty-two primary, alternately with an equal number of minute secondary septa, the latter being hardly recognisable in the dense vesicular tissue that they intersect, and these are united by more or less angular interseptal dissepiments. The central area is sub-circular and fully six lines broad, and in a transverse section exhibits the cut ends of the vertical lamellæ, which pass inwards. Four of these converge and meet a little off the centre on the one side, and three converge and meet on the opposite side of the centre of the central area, and about one line apart, producing a bicentral aspect, and are seen in the longitudinal section to be intersected by the cut edges of the tabulæ. The longitudinal section is triareal (Pl. I., Fig. 2B), in the central area there are thin discontinuous columellarian lines, and these are united by concave tabulæ. The intermediate ("interlocular") area is closed in by convex tabulæ. The outer ("interseptal") area is broad, and occupied by irregular lenticular convex cells—convexity pointing upwards and inwards—and arranged in oblique rows. The fossula is moderately large, and two of the primary septa, of shorter length than the others, extend into it.

Height of corallum, 3½ inches; diameter of calice, 1 inch 10 lines.

Formation and Locality.—Found in a bed of shale that overlies the lowest bed of Marine limestone at Thirdpart, Beith, Ayrshire.

This species is distinguished from the preceding by the bicentral arrangement of the lamellæ in the middle of the central area, which is considerably broader, and the interseptal tissue is less dense.

Centrephyllum trilamellum. *Thomson.* Sp. nov.

Plate I., Fig. 3.

Specific Characters.—Corallum simple, short, and conical. The epitheca is thin and marked with irregular encircling lines and shallow annulations of growth. The calice is circular, shallow, broad, and everted. The septa are lamellar and stout for three-fourths of their length from the inner ends. In the outer zone they are delicate and flexuous, and more or less dendriform, and there are twelve interlamellar plates in the space of a line. There are forty-two primary, alternating with an equal number of secondary septa. The latter extend inwards from the periphery for half the length of the primary, and all are united by numerous angular interseptal dissepiments. The central area is circular and composed of irregular lamellæ, which converge inwards, and three of the primary lamellæ meet in the centre of the calicular fossa. The fossula is large, and two of the primary septa, of shorter length than the others, extend into it.

Height of corallum, 1 inch 2 lines; diameter of calice, 1 inch 9 lines.

Formation and Locality.—Found at Charleston in a bed of shale overlying the lowest bed of marine limestone in that district.

This elegant specimen is distinguished from all the other species of the genus by its broad calice and acutely conical form, and by the presence of long slender secondary septa and the rudimentary central area.

Centrephyllum hexalamellum. *Thomson.* Sp. nov.

Plate I., Figs. 4, 4A.

Specific Characters.—Corallum simple, curved and turbinate, epitheca thin, with encircling lines and irregular annulations of growth. Calice subovate, and shallow in the centre. There is a prominent conical boss, formed by laminæ, a portion of which converge and meet at the crown of the conical boss. The septa are numerous, delicate, and bilamellar for four-fifths of their length from their inner margins; in the outer area they are thin and flexuous. There are fifty-six primary, and an equal number of secondary septa—the latter, where complete, extend inwards from the periphery for three lines, and all are united by irregular angular interseptal dissepiments. The central area is circular, and five lines in diameter, and in a transverse section exhibits the cut ends of twenty vertical lamellæ. Six of these pass into the centre of the columellarian area, the others fall short and become united to the six that meet in the centre. The fossula is well defined, and one of the primary septa extends for about half the length of the others into it.

Height of corallum, 1½ inches. There is, however, a small portion of the lower extremity wanting—probably about half-an-inch.

Formation and Locality.—Found at Brockley, Lesmahagow, Lanarkshire, in the lower carboniferous limestone.

This species is distinguished from the preceding by the small prominent conical boss and the greater number of the lamellæ in the central area, and by the fact that six of these lamellæ converge and meet in the centre of the central area, which suggests the specific name.

Centrephyllum granulatum. *Thomson.* Sp. nov.

Plate I., Fig. 5.

Specific Characters.—Corallum imperfect, the epitheca is thick, and there are encircling lines and annulations of growth. The specimen is so imperfect that I cannot correctly define its character. The calice is wanting. The septa are delicate and numerous. The primary septa are bilamellar for four-fifths of their length from the inner margin, and in the outer area they are flexuous, and the interseptal faces of each primary septum is minutely granular, from which I take the specific name. There is an equal number of secondary septa, which extend inwards from the periphery for three and a-half lines. They then bend and become united by irregular lenticular and angular interseptal dissepiments. The central area is six lines broad, and is occupied by fifteen lamellæ. One of these extends inwards from the fossula to the centre of the central area where it bifurcates and forms a small cell one line long and half a line broad; and five of the lamellæ converge inwards to the wall of the central cell. The others fall short of the centre, and become united to the six that approximately meet at the centre of the central area. The fossula is conspicuous, and there are three of the septa of shorter length than the others in it.

Height of corallum, imperfect specimen, 1½ inch long; diameter of section, 18 lines.

Formation and Locality.—Found at Thirdpart, Beith, Ayrshire, in a bed of a shale that overlies the lowest carboniferous limestone of the district.

This species is distinguished from all the other species of the genus by the possession of the granular structure along the lateral faces of the septa, and by the fact that a portion of the laminæ are intersepted in the centre of the central area. Indeed, from the possession of that cell in the centre, it may be said to be the primary divergence from the genus Centrephyllum into the next allied genus.

Centrephyllum cylindratum. *Thomson.* Sp. nov.

Plate II., Figs. 1, 1A, 1B, and 1C.

Specific Characters.—Corallum tall, slender, cylindrical, and conical near the inferior extremity. It is straight, and increases only slightly in width towards the superior or calicular end, continuing almost of the same diameter for a greater part of its length, while near its base it becomes conical. Indeed, it would seem that the secreting powers of the polype had dwindled away near its superior extremity. Epitheca imperfect, it being nearly all eroded away. There is left a small portion near the inferior extremity, sufficiently perfect for diagnostic purposes. What of it that remains is thin and coarsely granular, and marked with broad encircling lines and deep irregular annulations of growth. Calice imperfect, shallow, and everted. The central area is broad, and is slightly raised above the inner ends of the primary septa, and flat in the centre. The septa are stout, and in a transverse section are lamellar for three-fourths of their length from the inner ends, where they become thin and more or less flexuous; and there are nine interlamellar plates in the space of a line, which in a longitudinal section are seen to pass inwards and downwards (Plate II., Fig. 1B, *e.d.*). There are sixty-eight primary, and an equal number of minute secondary septa, and all are united by more or less angular interseptal dissepiments. The central area is fully eight lines broad, and is occupied by the cut ends of fourteen lamellæ, five of which converge inwards and unite in the centre of the calicular fossa. These may be regarded as primary lamellæ; the others fall short, coalesce, and become united to the five primary lamellæ.

The longitudinal section (Plate II., 1B) is triareal. In the middle of the central area there are discontinuous columellarian lines, and all are united by concave tabulæ, and the lateral margins are occupied by convex vesicular tissue, convexity pointing upwards and outwards. The intermediate ("interlocular") area is occupied by convex tabulæ.

The outer ("interseptal") area is formed by irregular lenticular convex cells, convexity pointing upwards and inwards, and arranged in oblique rows. Near the upper end of the section there is a portion of the interlamellar striæ exposed (*e*). Near the middle of the section are seen the cut ends of the bilamellar septa, exhibiting the interlamellar striæ passing inwards and downwards (*d*). The remarkable exposure of the lamina of the septa and the interlamellar striæ, as presented in this section, and indeed in all sections where the interlamellar striæ are seen, is due to the curvature of the corallum, as it is only when the sectioned coral is more or less curved and twisted—thus exposing the interlamina in a more or less diagonal section—that the stria can be at all seen.

The fossula is large, and three of the primary septa, of shorter length than the others, extend into it.

Height of corallum, 7 inches; diameter, 1 inch 3 lines.

Formation and Locality.—Found at Gateside, Beith, Ayrshire, in a band of shale that overlies the lowest beds of marine limestone of that district.

This species is distinguished from the preceding by its tall and slender form, its broad central area, by the extension of five of the lamellæ into the centre of the central area, and by its comparative large fossula.

Centrephyllum quadralamellum. *Thomson.* Sp. nov.

Plate II., Fig. 2.

Specific Characters.—Corallum simple, cono-cylindrical, tall, and curved. The epitheca is thin, and there are irregular encircling lines, and broad, deep, irregular annulations of growth. The calice is shallow, oval, and everted, and the centre of its floor is occupied by a calicinal boss, which is slightly raised above the inner ends of the septa, and formed by lamellæ, which converge and unite at its centre. One of the lamellæ is more prominent than the others, and passes into the fossula on the dorsal side of the corallum. The septa are lamellar for four-fifths of their length from the inner margin. In the outer zone they are delicate and slightly flexuous; and there are twelve interlamellar rectangular plates in the space of a line. There are sixty primary, alternating with an equal number of minute secondary septa, and all laterally united by more or less angular interseptal dissepiments. The central area is circular and eight lines broad. A transverse section exposes the cut edges of eighteen lamellæ. Four of these converge and meet in the centre, from which I take the specific name. The other lamellæ fall short of the centre, and coalesce with the four that meet in the centre. The fossula is moderate in size, and contains two short primary septa in it.

Height of corallum, 5½ inches; diameter of calice at the longest, 1¾ inches.

Formation and Locality.—Found in a band of shale that overlies the lowest bed of marine limestone in Langside Quarry, Beith, Ayrshire.

Centrephyllum pentalamellum. *Thomson.* Sp. nov.

Plate II., Fig. 3.

Specific Characters.—Corallum simple, short, conical, and curved; the epitheca is thin, and the exterior margin of the septa is visible from without through the thin epithical covering; and there are encircling lines and shallow annulations of growth. The calice is circular and imperfect.

The central area is broad and is occupied by the cut ends of twenty lamellæ, and the primary five converge and meet in the centre (from which I take the specific name) and each are united by the cut ends of the vesicular tissue they intersect. The septa are of two orders. There are sixty primary, alternating with an equal number of minute secondary septa, and each is united by interseptal dissepiments, which are minute as far as the secondary septa extends inwards, there they become sparse, and towards the interlocular area they are more or less angular and considerably more numerous, and in the interlocular area they are few in number. The primary septa are bilamellar from four-fifths of their length from the inner margins—then they are simple, and more or less flexuous towards the periphery, and the interlamellar area is occupied by the cut ends of the vertical stria, and there are eighteen stria in the space of a line. The fossula is moderately large and there are two of the primary septa of shorter length than the others in it.

Height of corallum, 3 inches; diameter of calice, 1 inch 10 lines.

Formation and Locality.—Found at Langside, near Beith, Ayrshire, in a bed of shale that overlies the lowest bed of limestone in that district. This species is distinguished from all the other species of the genus by the broad central area, the number of lamellæ, five of which converge and meet in the central area, and by the arrangement of the interseptal dissepiments.

Centrephyllum nudaphyllum. *Thomson.* Sp. nov.

Plate II., Figs. 4D and 4A.

Specific Characters.—Corallum simple, moderately tall, cylindrical, and abruptly conical near the base. Calice, circular, deep, and extends to within half an inch of the inferior extremity of the corallum. The epitheca is awanting, and there is no indication whatever of its having been worn or altered subsequent to its being secreted by the polype.

The exterior edges of the septa are laid bare. This remarkable development of the septa cannot be confounded with the ("Costai") or regarded as an independent structure, as each septum is continuous and complete, and only 2 lines in width.

There are sixty septa, which are lamellar, and extend from the inferior to the superior extremity of the corallum, and each is united by interseptal dissepiments, which are remote and few in number. There are eight interlamellar plates in the space of a line, the central area is circular and eight lines broad, and exhibits the cut edges of twenty lamellar. These and the septa are crushed and so much broken on the one side of the corallum that it is with difficulty I can make out their number, and from the same cause I cannot recognise the characteristics of the fossula.

Height of corallum, 2 inches 8 lines; diameter of section, 1 inch 1 line.

The transverse section is cut two lines below the superior extremity of the central area, which is only six lines from the inferior extremity of the corallum, and indicated by a transverse line.

Formation and Locality.—Found in a band of arenaceous shale that overlies the lowest beds of limestone at the south-east end of Charleston Quarry, Fifeshire. Indeed, I have found several specimens adhering to slabs of calcareous sandstone, and only in that part of the quarry.

This remarkable specimen is unique, and differs so widely from all the species hitherto discovered in the carboniferous rocks of Scotland, that I had considerable hesitation in deciding as to what group it could be placed amongst. Indeed, it was only after a second visit to the locality, and being fortunate in discovering the figured specimen (it being less crushed than those previously discovered), that I could decide into what group to place them. Although even the figured specimen is crushed, and to a great extent the structural characters of the central area are destroyed, yet in the specimen there is preserved fully a half of the central area, which enables me to define its classificatory value. Some of the other specimens discovered in this locality undoubtedly belong to this genus, yet they are so much crushed and destroyed that I cannot specifically describe them. One of them is 5 inches long, and the calice is 4 inches and 2 lines deep, and there is a thin epithecal covering which extends 6 lines upwards from the base of the corallum, and towards the superior extremity of the corallum the septa are uncovered, and there is no outer zone of interseptal dissepiments. In this specimen there is a septal fossula. It is my intention to visit this locality again, and hope to be fortunate enough to discover other specimens sufficiently well preserved near the base to allow me to specifically define the other forms now in my possession belonging to this group.

When we take into consideration the deep calice, fragile septa, and the conditions in which the polype lived, we can never hope to find any specimen preserved in its entirety, as the deposits in which they are found gives every indication that they lived near the shore, and their bathmical range was limited, and consequently they were exposed to the crushing and abrading influences of shallow water deposits.

Centrephyllum Nystii. *Thomson.* Sp. nov.

Plate II., Fig. 5.

Specific Characters.—Corallum simple, tall, slender, cylindrical, and slightly curved. Epitheca moderately stout, being embedded solid limestone. I am unable to describe the external aspect of e epitheca or calicular fossa. There are fifty-four primary septa, hich are strong and lamellar near their inner ends, while towards e periphery they are delicate and more or less flexuous. These ternate with an equal number of minute secondary septa, which tend inwards for about a line from the epitheca, and each is terally united by rectangular interseptal dissepiments. A portion the primary septa do not reach the outer wall, being intersepted large vesicular tissue, and in this respect resemble the genus *onsdalia* (M'Coy), plate iii., fig. 16, and *Thysanophyllum* (Nichol- n and Thomson). This species, however, differs from these genera the fact that their interseption is restricted to a few of the imary septa, and may therefore be regarded as an intermediate rm connecting the genus *Lonsdalia* and *Thysanophyllum* on e one hand, and *Centrephyllum* on the other—the structural aracteristics of *Centrephyllum* being largely predominant.

I feel justified in placing this interesting form amongst that oup. The central arc is circular and five lines in diameter. The ansverse section exhibits the cut ends of the vertical lamellae, ur of which converge and meet in the centre. The fossula is nall, and one of the primary septa, of shorter length than the hers, extends into it.

Height of corallum unknown, only a portion being discovered the solid limestone. Diameter of transverse section, 1 inch.

Formation and Locality.—Found embedded near the upper rface of the bed of limestone in Bowertrapping Quarry, Dalry, yrshire, which is the upper bed of marine limestone in Scotland.

This remarkable specimen is unique, and from the fact that it mbines the characters of *Lonsdalia*, *Thysanophyllum*, and *Centre- yllum*, it is readily distinguished from all the other forms yet iscovered belonging to the latter group. It is noteworthy that is is the only locality in which I have yet discovered any of the ore highly developed species of Rugose corals in that horizon in y portion of British strata.

I have much pleasure in dedicating this unique specimen in nour of my friend, Dr. Nyst, of Brussels.

Cyclophyllum, *fungties* of *Ure.*

Plate II., Figs. 6 and 6A.

Specific Characters.—Corallum simple, moderately tall, cylindero-conical, and curved. The epitheca is moderately stout. There are encircling lines and shallow annulations of growth. The calice is sub-circular and imperfect. A portion of the upper extremity of the periphery is eroded away.

The central area is cup-shaped and prominent. There are sixty-six primary, alternating with an equal number of secondary, septa. The latter extend inwards from the periphery for half the length of the former, and each is laterally united by rectangular interseptal dissepiments, which are few in number in the interlocular area, and numerous towards the periphery. There are twelve interlamellar striæ in the space of a line. The central area is obovate, five lines in diameter, and pointed towards the fossula, and exposes the cut ends of the dense vertical lamellæ, and is united to the inner margin of the primary septa by broad curved plates.

The longitudinal section is triareal, the central area exposes the discontinuous columellarian lines, and each is united by minute concave tabulæ. The interlocular area is broad, and occupied by more or less convex tabulæ. The interseptal area is occupied by irregular linticular convex cells, pointing upwards and inwards. The fossula is small, and one of the primary septa extends about half the length of the others into it.

Height of corallum, 2 inches, 4 lines. Diameter of section, 1 inch in the longest angle, and 11 lines in the shortest angle.

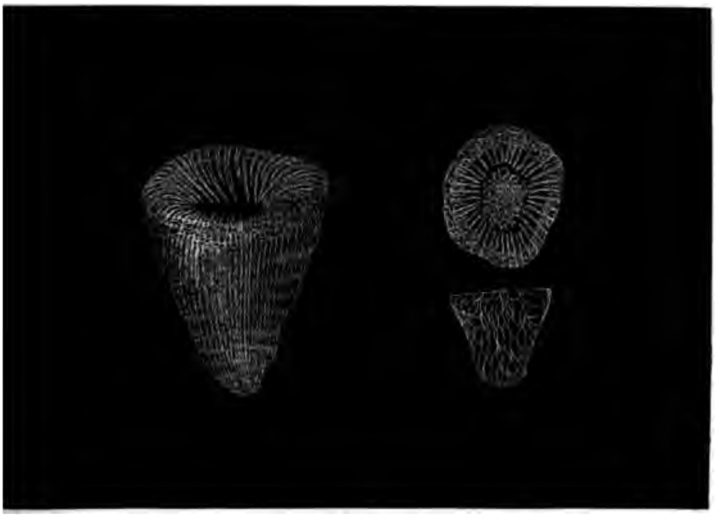
Formation, Carboniferous: Locality.—I am unable to say precisely in what locality in East Kilbride this interesting corallum was found.

The above are sections of the coral referred to, and figured by the Rev. David Ure, in his history of Rutherglen and East Kilbride, and named by him Fungites (page 328, plate xx., fig. 6), and now in the collection of the Royal Society of Edinburgh. The Council of that Society, through the late Dr. Page, a number of years ago, did me the honour of permitting me to make sections of the specimen, in order that its long-disputed characters might be satisfactorily delineated, and that it might be placed in its proper classificatory position.

Since then I have visited many localities in the parish of East Kilbride, and have discovered on the farm of Sheilds specimens similar in structure, fossilization, and preservation, and I am therefore persuaded that this specimen was found in the neighbourhood of that locality.

Carcinophyllum. *Thomson*. Gen. nov.

Fig. 3.



Generic Characters.—Corallum, simple, cylindro-conical, and cornute. Calice variable in depth; and some forms are everted, and exhibiting in the centre of their floor an elongated boss, which is lightly raised above the inner margin of the primary septa, which n a transverse section is seen to be composed of irregular reticulate cellular tissue. The septa are well developed, and of two orders, and never reach the centre of the visceral cavity, and each is united by more or less numerous interseptal dissepiments.

The internal structure is triareal. The central area is occupied by irregular anastomosing vesicular tissue, which surrounds a entral irregularly-formed median plate. The intermediate ("inerlocular") area is composed of the inner margins of the primary epta, and united by more or less angular dissepiments. The outer ("interseptal") area is occupied by the septa. The secondary epta extends inwards for a third of the length of the primary, nd near the periphery they are united by acutely angular and more or less sparsely developed interseptal dissepiments. There s a septal fossula.

The longitudinal section exhibits a series of sparse and irregular lates in the central area. The intermediate ("interlocular") area is occupied by large concave plates. The outer ("interseptal") area exhibits large sparse concave interseptal dissepiments, convexity inwards.

The genus which I propose to establish is for the reception of this group of corals, from the carboniferous rocks of Scotland, which present a combination of characters peculiarly their own. The type species, which accompanies this communication, I received from Mr. John Kirsop several years ago, and it would have been described before this, but in this, as in all the other groups which have passed through my hands, I have abstained from forming either new genera or species unless corroborative evidence was obtained. Since the reception of this remarkable specimen, I have discovered several forms, which are so closely related in their structural details, that I feel warranted in establishing a new genus for their reception. They are all from the lowest members of the carboniferous limestone, and found associated with other forms of coraline remains; indeed, in the horizon in which these forms were obtained, the coraline remains are more abundant than they are in any of the other members of that period.* As regards the genus *Carcinophyllum*, it is distinguished by characters of an unusually fundamental nature. In a transverse section the reticulate anastomosing structure of the central area, so widely different from all the other genera that has yet been discovered, is of itself sufficient to warrant us in establishing a new genus for their reception. In one respect it resembles several of the transitionary forms of the genus *Cyclophyllum* (Pl. II., Figs. 6 and 6A), in which the structure in the central area is more or less reticulate, but it is separated from that genus in not possessing an inner wall around the columellarian area. And the floor of the calice never presents the form of a small or inner cup, and in the longitudinal section of Carcinophyllum the lamellar plates are sparse, and the tabulæ are remote and hardly recognisable.

The type species resembles the genus "Lonsdalia," M'Coy (Pl. III., Fig. 16), from the fact that the septa do not reach the periphery, but are intersepted by a system of concave cells in the outer zone.

It is separated from that genus by the presence of a much more highly developed septal system, and the reticulate structure in the central area. In the longitudinal section of "Lonsdalia" there is a mesial plate in the columellarian area, which extends from the superior to the inferior portion of the corallum. In the genus under consideration the central area is composed of irregular, sparse, discontinuous, lamellar plates, and the endothecal dissepiments are hardly recognisable. It will thus be obvious that the structure of Carcinophyllum is quite distinct from that of Lonsdalia, the latter having a conical boss and a columellarian line in the central area, while in the former the central area is formed by loose anastomosing cellular tissue. So far as our present knowledge goes, the species of Carcinophyllum are confined to the lower carboniferous rocks. The type species is found at Arbigland, Dumfriesshire. The description of the various species I reserve for another communication.

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* The genus Carcinophyllum was named in *Annals and Mag. of Nat. History*, vol. xviii., Fourth Series, 1876, pp. 70-71, but it has not hitherto been described.

Carcinophyllum Kirsopiana. *Thomson.* Sp. nov.

Plate II., Figs. 7, 7A, and 7B.

Specific Characters.—Corallum simple and cylindro-conical; epitheca thin and mammillated internally, the mammillations are granular and connected to a system of elongated curved plates by delicate dissepiments; externally there are longitudinal striæ, and there are slight annulations of growth. The calice is sub-circular, everted, and moderately deep. The septa are well developed, and stout. There are forty-four primary, alternating with an equal number of secondary, septa, which extend inwards for a third of the length of the primary septa, and each is united by sparse and angular interseptal dissepiments.

The septa are surrounded by a system of elongated curved cellular tissue, which is connected to the epitheca by sparse and delicate dissepiments, which present around the inner margin of the everted periphery a series of elongated cells, and divided by sparse and delicate vertical plates attached to the mammillations in the interior of the epitheca. The fossula is small, and one of the primary septa, of shorter length than the others, is in it.

The longitudinal section is triareal, and the vertical lamellæ of the central area are discontinuous, curved, and are attached to the inferior lamellæ. In the intermediate ("interlocular") area there are large concave tabulæ. The outer ("interseptal") area is occupied by sparse lenticular convex cells—convexity pointing upwards and inwards.

Height of corallum, 13 lines; diameter, 11 lines.

Position and Locality.—Found at Arbigland, Dumfriesshire, in lower carboniferous rocks (Plate II., Fig. 6).

I have great pleasure in naming this species in honour of John Kirsop, Esq., to whom I am indebted for allowing me to add this form to our list of carboniferous corals.

Protocyathus. *Thomson.* Gen. nov.

Generic Characters.—Corallum simple, small, conical, and slightly curved, epitheca of variable stoutness, and there are delicate encircling lines and shallow annulations of growth. The calice is circular and deep, and extends to the base of the corallum in some forms, whilst in others it is circumscribed by a more or less irregular tabulæ. The septa are of two orders.

In those forms in which the calice is deep the primary septa are well developed. The younger coalesce with the older near the base of the corallum, the older extends inwards, bend upwards, coalesce, and form a loose cellular reticulate structure in the centre of the calicular fossa. The secondary septa are small and hardly recognisable, and each is incompletely united by sparse interseptal dissepiments; whilst in those forms in which the depth of the calice is circumscribed, the septa are rudimentary and slighty raised at their inner ends, and form a more or less convex irregular tabulæ, crowned with rudimentary ridges which converge to the centre of the visceral chamber.

The latter would seem to have been formed by the infolding of the wall of the polype. The fossula is small and of variable depth.

These small and delicate simple corals present characters alike interesting to the biologist and palæontologist. In one of the forms (Pl. III., Fig. 10) we have only four rudimentary septa developed, forming the prototype of the septal system of the rugose corals, and which suggested to me the generic name. In other forms there is a greater number of septa developed. In all cases they are multiples of four, and bilamellar—and with their increase in size and number there is a proportionate increase in the development of the interseptal dissepiments, whilst in the simpler forms the interseptal dissepiments are represented by rudimentary ridges. As regards the classificatory value of the group, I did regard the first-discovered specimens as belonging to the genus *Pyrgia* (E. and H.). Subsequently I discovered a greater number of forms which presented characters sufficiently distinct to warrant me in classifying them as a separate group, whose relations are *Pyrgia* on the one hand, and *Anisophyllum* (E. and H.), on the other. They also present characters which have a close affinity to the genus *Pentaphyllum* (Koninck), and the simpler forms have a close alley in the genus *Baryphyllum* (E. and H.). As regards its relationships it may be distinguished by characters of a fundamental nature.

The genus *Protocyathus* agrees with the genera *Pyrgia*, *Anisophyllum*, *Pentaphyllum*, and *Baryphyllum* in the following details :—

(1) The calice is deep.

(2) The septal system in the simpler forms is indistinct, and hardly recognisable.

(3) A number of the principal septa converge to the centre of the calicular fossa, and at the inner ends are slightly raised, and coalesce, forming a more or less reticulate cellular tissue. With these points of resemblance there are the following differences to be noted :—

Firstly,—In the genus *Pyrgia* the calice is deep, and extends to the base of the corallum ; and the septal system is represented by faint striæ, and do not coalesce in the centre, while in the simpler forms of *Protocyathus* the calice is shallow, and the rudimentary septa are more fully developed and bilamellar—at the inner ends are slightly raised, and the central area is closed in by irregular tabulæ.

Secondly,—In the genus *Anisophyllum* three of the septa are well advanced to the centre of the calice, and there is no columella. In *Protocyathus*, in the simple forms, the septa are represented in the form of slightly-raised ridges, which converge towards the centre, and are multiples of four.

Thirdly,—The genus *Protocyathus* agrees with *Pentaphyllum* in the arrangement of the structure in the central area, which, in *Pentaphyllum*, exhibits five of the principal septa, converging at their inner ends, and meeting in the centre of the calicular fossa. On the other hand, in *Protocyathus*, a portion of the older septa, of variable number, converge to the centre of the calice, then they are slightly raised and assume a more or less reticulate structure in the centre of its floor.

Fourthly,—There remains now to be considered the genus *Baryphyllum,* regarding which the only points calling for special remark are—The calice is superficial; three of the primary septa are well developed, and the inferior order run oblique with the principal septa. Thus, the superior extremity of the corallum presents in outline a marked distinction; as in *Protocyathus.* In some forms the calices are shallow, whilst in other forms the calices are deep, and a portion of the septa rise and converge at their inner ends, and present a more or less reticulate structure in the centre of the calice.

It will thus be apparent that this group forms a natural and distinct genus, belonging to which there are some of the most delicate and elegantly formed corals that I have yet discovered in the Scottish carboniferous limestone; and the simpler forms present characters which fill up the intermediate gap between the *tabulata* and the *rugosa* by the introduction of the rudimentary septa; and in proportion as the septa assume a more highly developed aspect, there is a proportionate increase in their number—in all cases increasing by multiples of four. We then have the primary development of the septa and interseptal dissepiments introduced, thus supplying an interesting link which we have long expected would be discovered, and which I now have the pleasure of recording.

Protocyathus Verrillii. *Thomson.* Sp. nov.

Plate III., Figs. 1 and 1A.

Specific Characters.—Corallum simple, turbinate, and curved. The calice is broad and deep, and extends to the base of the corallum. The epitheca is thin and smooth, and there are shallow annulations of growth. The septa are well developed, and of two orders. There are thirty primary, alternating with an equal number of secondary, septa. The latter are delicate, and extend inwards for a third of the length of the primary, septa. A portion of the primary septa unite at the base of the visceral chamber, and form a loose reticulate structure, and the centre of the central area is small. The interseptal dissepiments are few in number, and well developed.

The fossula is large, and two of the primary septa, of shorter length than the others, extend into it.

Height of corallum, 5 lines; diameter of calice, 4 lines.

Formation and Locality.—Found in decomposed shale, in Cunningham Baidland Quarry, Dalry, Ayrshire.

This species is distinguished from the other species of the genus by the greater development of the septa, by its large fossula, and the circumscribed central area, and the greater depth of the calice, and I have great pleasure in naming it in honour of Professor Verrill, the distinguished American naturalist.

Protocyathus Dalryences. *Thomson.* Sp. nov.

Plate III., Fig. 2.

Specific Characters.—Corallum simple, small, turbinate, and curved. The epitheca is smooth, and there are shallow annulations of growth. The calice is deep, and extends to near the base of the corallum, and its floor is reticulate. The lip is everted. The septa are well developed, and about half their length down from the superior extremity they abruptly project inwards, and thus circumscribe the calicular fossa. There are twenty primary, alternating with an equal number of secondary, septa. The latter extend inwards for a third of the length of the primary septa, and each is united by interseptal dissepiments. A portion of the primary septa curve upwards and coalesce at their inferior extremity, and form a dense reticulate structure in the centre of the floor of the calicular fossa.

The fossula is small, and one of the primary septa, two-thirds of the length of the others, extends down into it.

Height of corallum, 3½ lines; diameter of calice, 2½ lines.

Formation and Locality.—Found in the decomposed shale in Cunningham Baidland Quarry, Dalry, Ayrshire.

This elegant little species is distinguished from the other species of the genus by the dense reticulate structure of the floor of the calicular fossa, and the more highly-developed interseptal dissepiments.

Protocyathus serratus. *Thomson.* Sp. nov.

Plate III., Fig. 3.

Specific Characters.—Corallum simple, small, turbinate, and curved near the base. The epitheca is smooth, and there are shallow annulations of growth. The septa are well developed, and extend to the base of the corallum, where they converge inwards to the centre of the calicular chamber and curve upwards, coalesce, and form a more or less reticulate structure in the centre of its floor. There are twenty-four primary septa alternating with an equal number of secondary septa, and the faces of the septa are minutely serrated. There are no interseptal dissepiments.

The fossula is small, and contains one septum of shorter length than the others in it.

Height of corallum, 5 lines; diameter of calice, 3½ lines.

Formation and Locality.—Found in the decomposed shale in Cunningham Baidland Quarry, Dalry, Ayrshire.

Protocyathus plicatus. *Thomson.* Sp. nov.

Plate III. Figs. 4, 4A

Specific Characters.—Corallum simple, more or less conical, and slightly curved. The epitheca is thin, smooth, and there are longitudinal ridges and plications, from which I take the specific name. The calice is deep and extends to the base of the corallum. The septa are rudimentary and a portion of them pass to the inferior extremity of the corallum. There are eight primary, alternating with an equal number of secondary, septa, and the interseptal dissepiments are indicated by faint and hardly recognisable transverse ridges and depressions. The fossula is large, and two rudimentary septa, of shorter length than the others, extend into it.

Height of Carallum, 8 lines ; diameter of calice, 4 lines.

Formation and Locality.— Found in the decomposed shale, Cunningham Baidland Quarry, Dalry, Ayrshire.

Protocyathus contortus. *Thomson.* Sp. nov.

Plate III., Figs. 5 and 5A.

Specific Characters.—Corallum simple, small, conical, and contorted. The calice is deep, and extends half the depth of the corallum, and its floor is slightly raised above the inner ends of the primary septa and slightly conical, and exhibits seven lamellar ridges and a loose reticular eudothical structure in the centre of its floor, produced by the prolongation of a portion of the primary septa to the centre of the visceral chamber, where they coalesce and form the loose reticulate structure. The epitheca is thin, and there are circling lines and irregular annulations of growth. The septa e rudimentary. There are twenty primary, alternating with an ual number of secondary, septa, and the interseptal dissepiments e represented by indistinct transverse ridges. The fossula is all, and one of the primary septa, of shorter length than the hers, is in it.

Height of corallum, 7½ lines; diameter of calice, 3 lines. The lice of the two forms yet discovered are both contorted to the side the corallum, but in opposite directions.

These remarkably contorted forms exhibit characters which are fficiently distinct from all the other species of the genus to arrant their being placed in a separate species. I did regard em when first discovered as being closely allied to the genus *mplexus*, an opinion provoked by the rudimentary septa and the oad central area; but on removing a portion of the epitheca I vealed the septa at their inner ends, converging to the centre of e visceral chamber, and the loose reticulate structure of the cenal area.

Protocyathus spinolosus. *Thomson.* Sp. nov.

Plate III., Figs. 6 and 6A.

Specific Characters.—Corallum simple, cylindro-conical, and rved. The epitheca is thin, and continuous on the one side of e corallum, while on the other is interrupted in the middle, d assumes a semicircular double cup, which may have been oduced by the rupturing of the polype from the sclerodermic atter, thus involving the fission of a portion of the parent calice the one side, while the original coral continued to grow interruptedly on the other. There are encircling lines and allow annulations of growth, and on the ventral side of the rallum there are numerous spinous projections. The calice is ep, extending to near the base of the corallum. The septa are dicated by faint lines at their superior, while these increase and e more fully developed at their inferior extremity. A portion them converge to the centre at the base of the calicular cavity. ere are eight primary, alternating with an equal number of condary, septa, and each is united near their inner ends by a ansverse plate, which converges inwards and downwards towards e base of the calicular cavity.

Height of corallum, 6 lines; diameter of calice, fully 2 lines.

Formation and Locality.—Found in the decomposed shale in Cunningham Baidland Quarry, Dalry, Ayrshire.

Protocyathus elegance. *Thomson.* Sp. nov.

Plate III., Fig. 7.

Specific Characters.—Corallum simple, small cornute, and conical. The epitheca is thin, smooth, and there are shallow annulations of growth. The calice is deep, and extends to the base of the corallum. The septa are well developed, and a portion of them extends to the base of the calicular cavity, whilst others stop short and coalesce with older septa. There are twenty septa, and there are faint indications of interseptal dissepiments. The floor of the calicular cavity is slightly raised, and there are delicate ridges produced by the slightly elevated inner ends of older septa.

The fossula is small, and one of the septa, of shorter length than the others, extends into it.

Height of corallum, 3 lines; diameter of calice, 2 lines.

Formation and Locality.—Found in Cunningham Baidland Quarry, Dalry, Ayrshire, in the same horizon as the preceding forms.

Protocyathus pachytheca. *Thomson.* Sp. nov.

Plate III., Figs. 9 and 9A.

Specific Characters.—Corallum simple, small, conical, and cylindro-conical. The epitheca is thick, smooth, and there are irregular shallow annulations of growth. The septa are well developed; a portion of them extend to the base of the calicular cavity, and at their inferior extremity curve upwards, coalesce and assume a more or less reticulate structure. There are twenty septa, and the interseptal dissepiments are rudimentary and few in number. The fossula is small, and one of the primary septa, of shorter length than the others, passes into it.

Height of corallum, 5½ lines; diameter of the superior extremity is 4 lines.

Formation and Locality.—Found in the decomposed shale in Cunningham Baidland Quarry, Dalry, Ayrshire.

This species is readily distinguished from the other species of this genus by its remarkable thick wall; in the type species the diameter of the superior extremity is 4 lines, while the diameter of the mouth of the calice is 2¼ lines.

Protocyathus quadraphyllum. *Thomson*. Sp. nov.

Plate III., Figs. 10 and 10A.

Specific Characters.—Corallum simple, small, cylindro-conical, and curved. The epitheca is thin and smooth, with irregular annulations of growth, and there are several tubercular projections. The calice is deep. The septa are rudimentary and converge to the centre, and are seen in the crown of the tabulæ in the form of slightly raised ridges. There are four primary septa, and the spaces between are minutely mammillated, indicating the development of the septal system. The wall of the calice is thin, and the interseptal dissepiments are indicated by slightly transverse depressions. There are indications of a rudimentary fossula, but so ill-defined that meanwhile I am unprepared to describe it.

Height of corallum, 5 lines; diameter of calice, 2 lines.

Formation and Locality.—Found in decomposed shale, which is interstratified with thin bands of impure limestone, that overlies the lowest bed of carboniferous limestone in Cunningham Baidland Quarry, Dalry, Ayrshire.

This remarkable little specimen was in my possession for a considerable time before I could decide into what group it ought to be placed.

At first I was led to believe that it might belong to some of the species of *Lithostrocian*, with which it is found associated. I have, however, since examined with considerable care fragments of the lower extremities of the various varieties of *Lithostrocian* found in that locality; and in all cases the septal system of this group is developed immediately after the secretion of the epitheca at the base of each coralet—a difference of structure sufficiently distinct to warrant me in placing this interesting little specimen as the type of the genus.

Pyrgia. *Edwards* and *Haime*.

Generic Characters.—Corallum simple, small, cornute; epitheca moderately stout, and there are faint annulations of growth. Calice circular and deep. The septa ("pseudo-septa") are represented by faint lines or striæ. They do not coalesce in the centre of the calicular fossa.

Pyrgia Labechia. *Edwards* and *Haime.*

Plate III., Figs. 8 and 8A.

Specific Characters.—Corallum simple, small, and cornute; epitheca moderately stout, and there are faint annulations of growth. Calice circular and deep. It extends to the base of the corallum. The septa ("pseudo-septa") are represented by faint lines or striæ, which do not coalesce in the centre of the calicular cavity.

Height of corallum, 2 lines; diameter of calice, 1 line—a portion of the upper extremity of the corallum is wanting. I have another specimen complete, 1½ lines long; diameter, 1 line.

Formation and Locality.—Found at Cunningham Baidland, Dalry, Ayrshire.

These delicate little specimens agree so closely with Edwards and Haime's species, that I feel that I am justified in recording it as occurring in the West of Scotland.

While thus recording the occurrence of this interesting little genus, it is noteworthy to remark that Prof. Nicholson, in his work on "The Structure and Affinities of the Tabulate Corals of the Palæozoic Period," and also in a paper by Prof. Nicholson and Mr. Robt. Etheridge, Jun., which appeared in the *Geo. Mag.*, Dec. 2, vol. vi., July, 1879, delete the genus *Pyrgia*, and consider that it was founded upon certain forms of Cladochonus of M'Coy, and assign the following reasons for their opinions:—

"The genus Aulopora Goldfuss. The corallum in Aulopora has the form of a creeping, branched or reticulate, system of tubes, attached by the whole of the lower surface to the exterior of a shell or coral, or other foreign body. The basal and prostrate stolons send up tubular or trumpet-shaped coralets at longer or shorter intervals, but, though the terminal portions of these are free, the length of the tubes is always limited, and the reclined coralets never grow up into a fasciculate mass.

"The walls of the coralets are quite compact, and the tubes are for the most part not in contact with one another in any part of their extent. In cases, however, where the tubes come in contact to any extent, it may not impossibly be found that mural pores exist at the points of union.

"The septa are quite rudimentary in the form of marginal striæ or vertical rows of tubercles.

"Lastly, the continuity of the visceral chamber is interfered with, in certain species at any rate, by complete transverse tabulæ." Prof. Nicholson ("Tabulate Corals of the Palæozoic Period," pages 219 and 220).

M'Coy proposed the genus Cladochonus in 1847 (*Annls.* and *Mag. Nat. Hist.*, ser. 1, vol. xx., page 227), "for some Australian corals which he believed to be similar to Edwards' and Haime's genus Pyrgia," and established the genus Cladochonus and deleted the genus Pyrgia. Professor Nicholson, in his work on Tabulate Corals (page 222) states, "There seems further to be no reasonable doubt that the genus Pyrgia, Edwards and Haime (*Pal. Foss. des Terr. Pal.* p. 310, 1851), is really founded upon the forms of Cladochonus (M'Coy), and that it must, therefore, be withdrawn in favour of the latter." And again, at page 223, he states that Nicholson and Etheridge, Jun., in their investigation of Cladochonus, had discovered a form which differed so widely that they had established a new genus for its reception. "The minute structure of Monilopora, as elucidated by means of thin sections, has been shown by M. Rofe (*Geol. Mag.*, vol. vi., page 352, 1869), and subsequently more fully by Mr. R. Etheridge, Jun., and myself, to be of a most remarkable character. The entire visceral cavity of each polype is open from top to bottom, and we have been unable to detect any traces of tabulæ. "The wall of the theca is exceedingly thick, and throughout the greater part of its extent it seems to consist wholly of delicate concentric layers of sclerenchyma, firmly united with one another, and which are crossed at right angles by numerous delicate cross-bars or trabiculæ of sclerenchyma."

Further on he states—"In a typical species of Cladochonus, such as the carboniferous Cladochonus (Pyrgia) Michelini—Edwards and Haime—the corallum has the form of a slender erect branching colony, composed of long conical coralets, and which are produced by lateral budding, the entire growth being fixed basally to some foreign object by one or more isolated points of attachment." An excellent description of this singular coral is given by De Koninck (*Nouv. Rech. sur les au Foss.*, p. 153, Plate XIV., Fig. 6, 1872), and this accurate observer states that the visceral chambers of the coralets are entirely hollow, and that they communicate freely with one another by their bases. The latter point is doubtless correct.

Frequently only single or independent examples of Aulopora, Cladochonus, and Monilopora are found, but these corals must nevertheless be considered as compound forms. Sometimes large specimens occur showing buds or gemmæ bursting from the lateral margin of the calice of the parent coral. Still, I have never met with either of the genera so large, and in no instance do they assume a similar external aspect; and the pseudo-septa are never so distinctly marked as we find in the genus "Pyrgia," and the latter has always the usual appearance of a single and simple coral. It would thus seem that the distinguishing characters of those genera may be summarized as follows:—

First,—Monilopora, by the thickness of the wall, which is formed by delicate concentric layers of sclerenchyma firmly united with one another by delicate transverse bars of sclerenchyma.

Second,—Cladochonus, in always developed in the form of a branching colony, composed of long conical coralets, and produced by lateral budding.

Third,—Aulopora is in the form of creeping branches, or reticulate system of tubes attached by the whole of the lower surface to foreign bodies, and the interruption of the visceral chambers by complete transverse tabulæ.

Fourth,—Pyrgia is a simple coral, the calice is deep, there is no tabulæ, and the rudimentary septa extends to the lower extremity of the corallum.

Such important differences between Pyrgia on the one hand, Monilopora, Cladochonus, and Aulopora, on the other, are of too fundamental a nature to permit of one associating these genera or any of them as a single genus. In fact, Cladochonus, as defined by M'Coy, does not agree in any respect with Pyrgia, as described by Edwards and Haime. If, therefore, those authors have not been misled by the examination of specimens greatly altered by fossilization, it is clear that the specimens described by them under the name of Cladochonus do not belong to the genus Pyrgia.

Cyathophyllum echinatum. *Thomson.* Sp. nov.

Plate III., Figs. 15 and 15A.

Specific Characters.—Corallum cylindro-conical and slightly curved; epitheca thin, with delicate encircling lines and shallow annulations of growth. The septa are numerous, and bilamellar in the central zone. In the outer area, near the periphery, and at their inner ends, they are delicate and single. There are forty primary, alternating with an equal number of secondary, septa.

he latter extend inwards and downwards from the periphery for wo-thirds of the length of the former, and each is united by ectangular interseptal dissepiments, which are numerous in the uter zone and few in number in the interlocular area.

There are ten interlamellar plates, which, in a longitudinal ection, extend downwards and outwards (Plate III., Fig. 15A), nd along the lateral margins of each septum there is a series of inute spines, from which I take the specific name. The central rea is three lines broad, and occupied by more or less flat tabulæ. he longitudinal section is triareal. The central area exposes the t edges of the transverse tabulæ. The intermediate ("interlocu-ar") area is occupied by concave tabulæ. The outer ("interseptal") rea is broad, and occupied by minute, elongated, irregular, conex cells, convexity pointing upwards and inwards, and arranged oblique rows. The fossula is small, and one of the septa, of orter length than the others, passes into it.

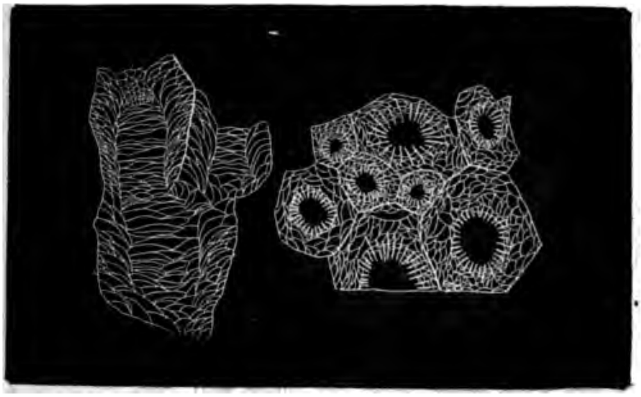
Height of corallum, 1 inch 9 lines; diameter of transverse section, ½ lines.

Formation and Locality.—Found in a bed of shale four feet bove the lowest bed of limestone, in Gateside Quarry, Beith, yrshire.

The interlammellar plates of this, and several other species elonging to the same group, pass downwards and outwards, whilst all the other forms I have as yet discovered, in which this tructure is preserved, the plates pass inwards and downwards.

Thysanophyllum. *Nicholson* and *Thomson.* Gen. nov.

Fig. 4.



Generic Characters.—Corallum compound, fasciculate, or astræiform, increasing by latro-calicular gemmation. Each corallet is provided with a distinct wall, and there is an inner mural investment developed.

The calice is shallow, and the centre of its floor is occupied by broad and remote tabulæ. The septa are of two orders, and do not reach the outer wall. They are intercepted by a zone of large vesicles, which surround the periphery. The primary septa extends from the vesicular tissue inwards to the tabulæ, and the secondary septa extends inwards for a fourth of the length of the primary septa, and each is united by slightly angular interseptal dissepiments, which are sparse near the inner margin of the primary septa, and where they approach the vesicular tissue of the outer zone.

The longitudinal section is triareal; the central area is composed of remote transverse tabulæ. The intermediate ("interlocular") area is composed of convex tabulæ, convexity pointing inwards and upwards. The outer area is occupied by a zone of vesicular tissue.

The genus *Thysanophyllum* (which was recorded in abstract in the *Proceedings of the Royal Society of Edinburgh*, vol. ix., p. 149, [illegible] 1876, by Nicholson and Thomson) was proposed for two species of astræiform corals, from the carboniferous rocks of Scotland. This genus is related to *Lonsdalia* (M'Coy) Plate III., Fig. 16, in the general form of the corallum, in the presence of an exterior vesicular zone of large cells, and in the possession of septa which have no connection with the outer wall.

It is distinguished, however, by the fact that there is no true columella, and there is always a conspicuous central tabulate area uncovered and exposed to view in the former, whilst in the latter the centre of the calicular cavity is occupied by a prominent boss, and by the possession of a median columellarian line, which extends from the superior to the inferior extremity of the corallum, which is surrounded by convex vesicular tissue, convexity pointing upwards and outwards.

In the longitudinal section it presents characters in the central area which might be mistaken for some of the simple forms of *Cyathophyllum*. From the broad tabulate forms of *Cyathophyllum* the genus *Thysanophyllum* is at once distinguished by the fact that the septa extend to the outer wall in the former, whilst in the latter the septa never reach the outer wall, but are intersepted and surrounded by a zone of vesicular tissue which occupies the intermediate space between the outer ends of the septa and the periphery of the corallum.

Thysanophyllum orientale. *Nicholson* and *Thomson.* Sp. nov.

Plate III., Figs. 14, 14A, 11, and 11A.

Specific Characters.—Corallum compound, fasciculate, or astræiform, increasing by calicular gemmation. Each coralet is provided with a distinct epitheca, the specimens being embedded in compact crystalline limestone. I am unable to state what external aspects the epitheca presented, and from the same cause I am unable to describe the characters of the calice. The centre of the visceral chamber is occupied by broad tabulæ. The septa are bilamellar, and they never extend to the periphery. They are intersepted by a zone of vesicular tissue. In an ordinary-sized coralet there are about 30 septa, which extend from the tabulæ of the central area to the vesicular tissue of the outer zone. The longitudinal section (Figs. 11A and 12A) exhibits the cut edges of the transverse tabulæ of the central area, and the large convex vesicular cells in the outer area, convexity pointing upwards and inwards.

Height of corallum, 4 inches; diameter, 3½ inches.

Formation and Locality.—Found embedded in a bed of shale associated with *Lithostrocian juneum* (Fleming) on the shore of Aberlady Bay, Haddingtonshire.

This shale is a few feet above the lowest beds of marine carboniferous limestone of that district.

Thysanophyllum minus. *Nicholson* and *Thomson.* Sp. nov.

Plate III., Figs. 12 and 12A.

Specific Characters.—Corallum compound, fasciculate, or astræiform, and increasing by calicular and fossiperous gemmation. The corallum is found embedded in compact limestone, consequently I am unable to describe the characters of the calicular fossa. The centre of the visceral chamber is occupied by broad tabulæ. The epitheca is stout, and there are longitudinal ridges and delicate encircling striæ.

The septa are bilamellar and flexuous, and one of them extends

Generic Characters.—Corallum compound, fasciculate, or astræoform, increasing by latro-calicular gemmation. Each coralet is provided with a distinct wall, and there is an inner mural investment developed.

The calice is shallow, and the centre of its floor is occupied by broad and remote tabulæ. The septa are of two orders, and do not reach the outer wall. They are intercepted by a zone of large vesicles, which surround the periphery. The primary septa extends from the vesicular tissue inwards to the tabulæ, and the secondary septa extends inwards for a fourth of the length of the primary septa, and each is united by slightly angular interseptal dissepiments, which are sparse near the inner margin of the primary septa, and where they approach the vesicular tissue of the outer zone.

The longitudinal section is triareal; the central area is composed of remote transverse tabulæ. The intermediate ("interlocular") area is composed of convex tabulæ, convexity pointing inwards and upwards. The outer area is occupied by a zone of vesicular tissue.

The genus *Thysanophyllum* (which was recorded in abstract in the *Proceedings of the Royal Society of Edinburgh*, vol. ix., p. 149, 1876, by Nicholson and Thomson) was proposed for two species of astræiform corals, from the carboniferous rocks of Scotland. This genus is related to *Lonsdalia* (M'Coy) Plate III., Fig. 16, in the general form of the corallum, in the presence of an exterior vesicular zone of large cells, and in the possession of septa which have no connection with the outer wall.

It is distinguished, however, by the fact that there is no true columella, and there is always a conspicuous central tabulate area uncovered and exposed to view in the former, whilst in the latter the centre of the calicular cavity is occupied by a prominent boss, and by the possession of a median columellarian line, which extends from the superior to the inferior extremity of the corallum, which is surrounded by convex vesicular tissue, convexity pointing upwards and outwards.

In the longitudinal section it presents characters in the central area which might be mistaken for some of the simple forms of *Cyathophyllum*. From the broad tabulate forms of *Cyathophyllum* the genus *Thysanophyllum* is at once distinguished by the fact that the septa extend to the outer wall in the former, whilst in the latter the septa never reach the outer wall, but are intersepted and surrounded by a zone of vesicular tissue which occupies the intermediate space between the outer ends of the septa and the periphery of the corallum.

Thysanophyllum orientale. *Nicholson* and *Thomson*. Sp. nov.

Plate III., Figs. 14, 14A, 11, and 11A.

Specific Characters.—Corallum compound, fasciculate, or astræiform, increasing by calicular gemmation. Each coralet is provided with a distinct epitheca, the specimens being embedded in compact crystalline limestone. I am unable to state what external aspects the epitheca presented, and from the same cause I am unable to describe the characters of the calice. The centre of the visceral chamber is occupied by broad tabulæ. The septa are bilamellar, and they never extend to the periphery. They are intersepted by a zone of vesicular tissue. In an ordinary-sized coralet there are about 30 septa, which extend from the tabulæ of the central area to the vesicular tissue of the outer zone. The longitudinal section (Figs. 11A and 12A) exhibits the cut edges of the transverse tabulæ of the central area, and the large convex vesicular cells in the outer area, convexity pointing upwards and inwards.

Height of corallum, 4 inches; diameter, 3½ inches.

Formation and Locality.—Found embedded in a bed of shale associated with *Lithostrocian juneum* (Fleming) on the shore of Aberlady Bay, Haddingtonshire.

This shale is a few feet above the lowest beds of marine carboniferous limestone of that district.

Thysanophyllum minus. *Nicholson* and *Thomson*. Sp. nov.

Plate III., Figs. 12 and 12A.

Specific Characters.—Corallum compound, fasciculate, or astræiform, and increasing by calicular and fossiperous gemmation. The corallum is found embedded in compact limestone, consequently I am unable to describe the characters of the calicular fossa. The centre of the visceral chamber is occupied by broad tabulæ. The epitheca is stout, and there are longitudinal ridges and delicate encircling striæ.

The septa are bilamellar and flexuous, and one of them extends to the centre of the visceral chamber. They never reach the periphery, but are intersepted by a zone of large celular tissue. The longitudinal section (Plate III., Fig. 12A), exhibits the cut ends of the transverse tabulæ and the large convex cells of the outer zone, convexity pointing upwards and inwards.

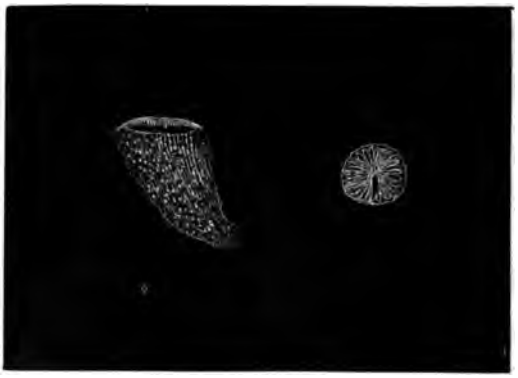
Height of corallum, 6 inches; diameter of section, 5 inches.

Formation and Locality.—Found in a bed of impure limestone, which is about five feet above the lowest bed of marine limestone at Peter's Hill, near Bathgate, Linlithgowshire.

This species is readily distinguished from the preceding by the smaller coralets, the flexuous septa and a septum in each coralet always extending along the superior face of the tabulæ to the centre of the visceral chamber.

Zaphrentis Smithii. *Thomson.* Sp. nov.

Fig. 5.



Specific Characters.—Corallum simple, small, cono-cylindrical, and curved; epitheca stout, with minute annulations of growth, and there are slightly raised longitudinal ridges, extending more or less from the superior to the inferior extremity of the corallum, and presenting at irregular distances along the crown of the ridges a series of elongated tubercles.

The calice is deep, with a large and conspicuous fossula, which is seen in a transverse section to be formed by the coalescence of a portion of the septa, which folds round and forms its walls.

There are twenty-eight septa, which are stout toward their outer margins, and become attenuated, and extend inwards to the centre of the visceral chamber. The fossula is large, and extends into the centre of the calicular cavity, and situated on the ventral or concave side of the corallum. One of the septa, of shorter length than the others, is included in it.

Height of corallum, 10 lines; diameter of calice, 6 lines.

Position and Locality.—Found in Auchenskeoch Quarry, Dalry, Ayrshire, in a band of shale about 12 feet above the lowest bed of carboniferous limestone in that district.

This species is distinguished from all the other species of the genus by the prominent longitudinal ridges on the epitheca, and by the presence of numerous elongated tubercles along the crown of the ridges. It is closely allied to *Zaphrentis Koninckii* (E. and H.); it, however, differs from that species by the presence of a larger fossula, and the nodular aspect of its external wall.

In external aspect it resembles "Amplexus modulosus." Being, however, satisfied that in all cases it is absolutely necessary to cut transversely fossil corals before we can determine either genera or species, I had this interesting little coral cut, and found that it possessed characters sufficiently distinct to warrant me in adding it as a new species to the genus *Zaphrentis*, and I have great pleasure in naming it in honour of its discoverer, Mr. John Smith, Eglinton Iron-works, Kilwinning, to whom I offer my thanks for allowing me to add it to the list of this interesting genus.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1.—*Centrephyllum subcentricum*, a transverse section, natural size. Lower carboniferous, Thirdpart, Beith, Ayrshire.

,, 1A.—A longitudinal section of the same, natural size. The letter B points to a small portion of the interlamellar stria exposed where the corallum was curved. In cutting the longitudinal section at the curved part, the section passes diagonally between the lamellæ of the septa, and thus exposes the stria.

,, 2.—*Centrephyllum bicentricum*, showing the floor of the calice and the arrangement of the lamellæ. Lower carboniferous, Thirdpart, Beith, Ayrshire.

,, 2A.—A transverse section of the same, natural size.

,, 2B.—A longitudinal section of the same, natural size, the interlamellar stria and the cut ends of the inner ends of the septa are exposed at the curved portions of the corallum.

,, 3.—*Centrephyllum trilamellum*, a transverse section, natural size. Lower carboniferous, Charleston, Fifeshire.

,, 4.—*Centrephyllum hexalamellum*, showing the floor of the calice, the everted periphery, and the arrangement of the centre of its floor. Lower carboniferous, Brockley, Lesmahagow, Lanarkshire.

,, 4A.—A transverse section of the same, natural size.

,, 5.—*Centrephyllum granulatum*, natural size. Lower carboniferous, Thirdpart, Beith, Ayrshire.

,, 6.—*Clisiophyllum*, natural size. Lower carboniferous, Broadstone, Beith, Ayrshire.

PLATE II.

Fig. 1.—*Centrephyllum cylindratum*, showing in outline the size of the corallum and the calice at the superior extremity. Lower carboniferous, Gateside, Beith, Ayrshire.

,, 1A.—A transverse section of the same, natural size. This section is cut 1½ inch from the crown of the corallum.

,, 1B.—A longitudinal section of the same, and cut 3 inches from the superior extremity, natural size, showing the interlamellar stria, the cut ends of the septa and the interlamellar stria passing diagonally between the lamellæ of the septa.

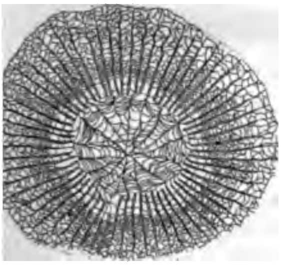
,, 1C.—A transverse section of the same, natural size. Cut 1 inch from the inferior extremity of the corallum.

,, 2.—*Centrephyllum quadralamellum*, a tranverse section, natural size. Lower carboniferous. Langside, Beith, Ayrshire.

,, 3.—*Centrephyllum pentalamellum*, a transverse section, natural size. Lower carboniferous, Langside, Beith, Ayrshire.

,, 4.—*Centrephyllum nudaphyllum* represents the external aspect of this remarkable corallum. It is much crushed and broken in the centre. Lower carboniferous, Charleston, Fifeshire.

Fig.1



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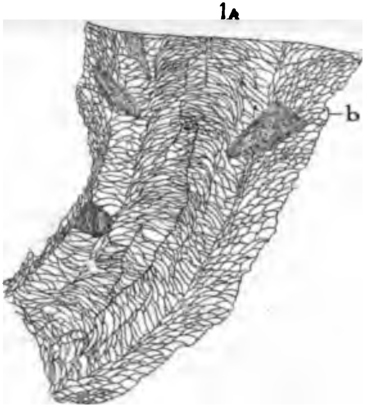

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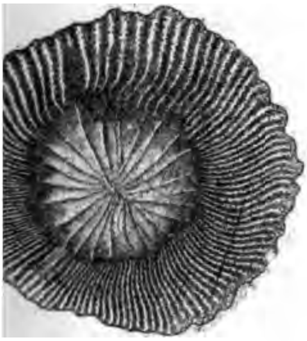

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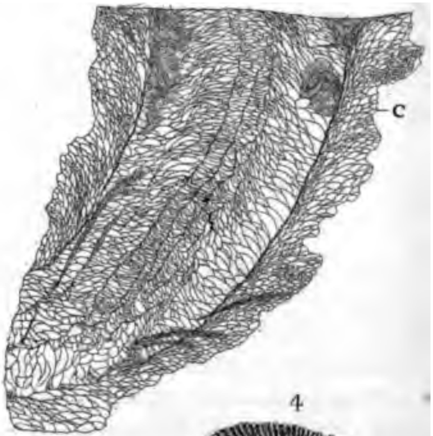

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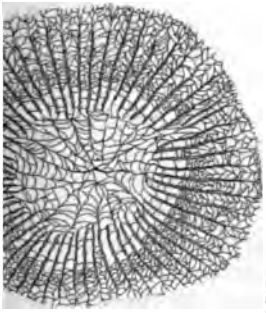

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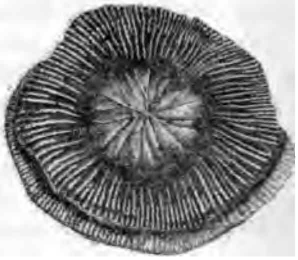

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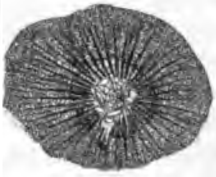

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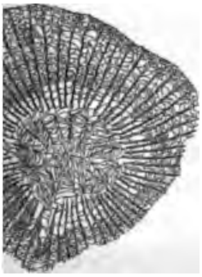

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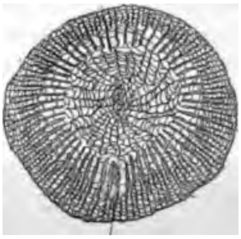

4A

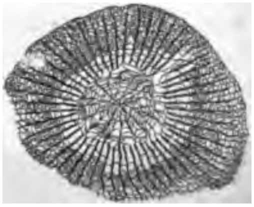

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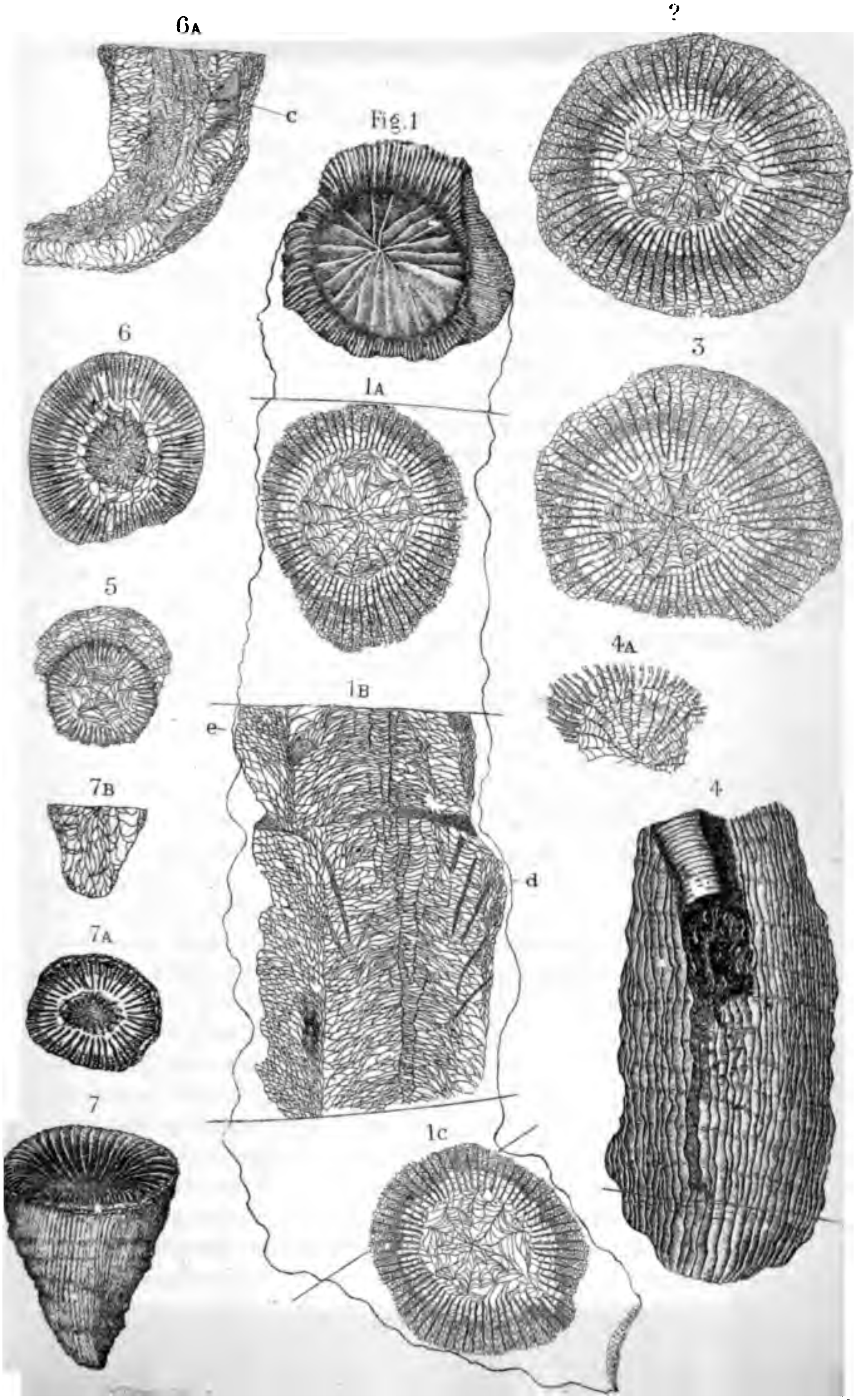
Plate II.



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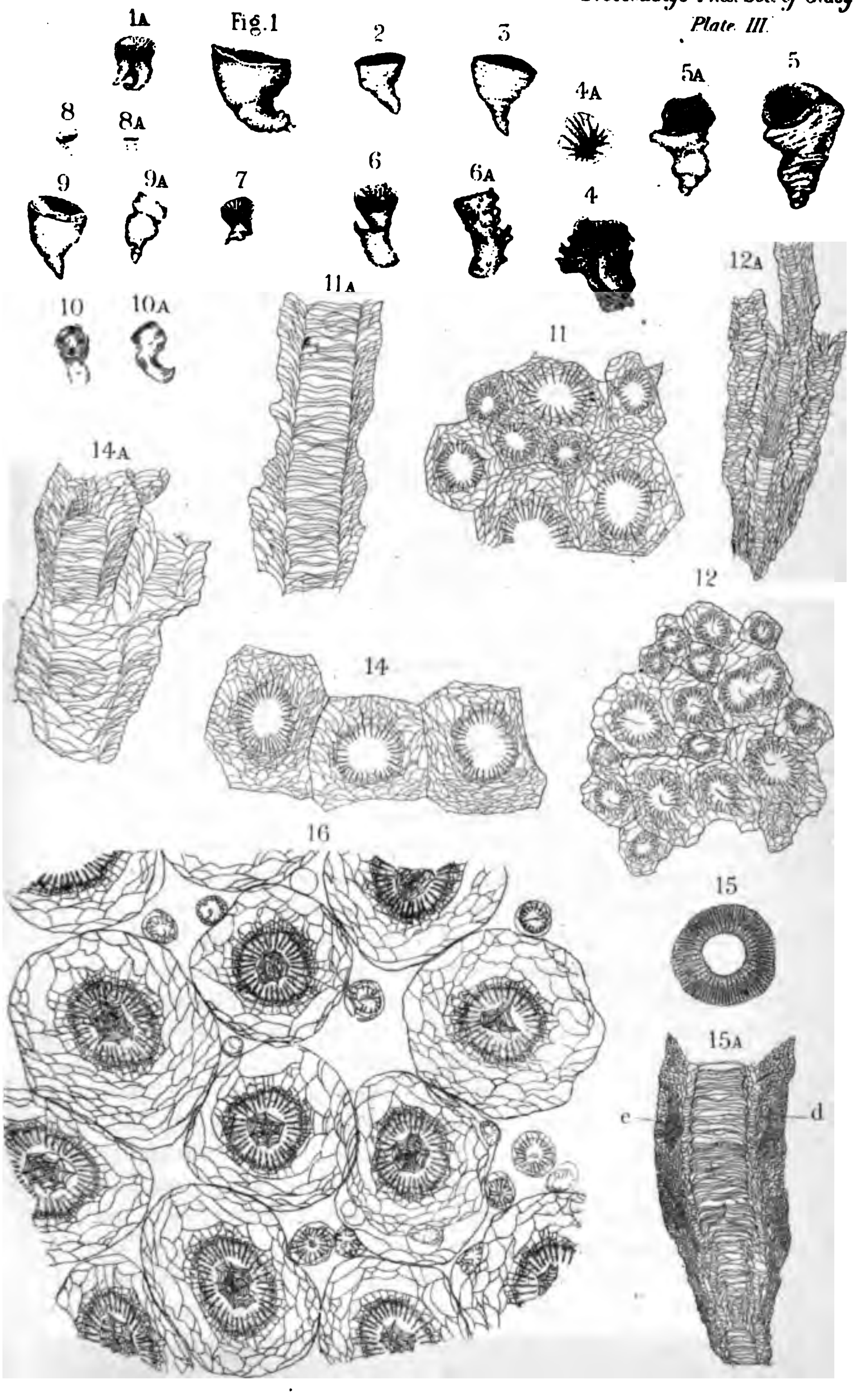
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Fig. 4A.—A transverse section of the same, natural size. The portion not represented is so much crushed and broken that I could not restore it.

,, 5.—*Centrephyllum Nystii*, a transverse section, natural size. Upper carboniferous limestone, Bower-trapping, Dalry, Ayrshire.

,, 6.—*Cyclophyllum fungites*, a transverse section, natural size. Lower carboniferous, supposed to be from near Shields, East Kilbride, Lanarkshire.

,, 6A.—A longitudinal section of the same, natural size, showing the interlamellar striæ at E. In the collection of the late Rev. David Ure, author of "The History of Rutherglen and East Kilbride," and now in the collection of the Royal Society of Edinburgh.

,, 7.—*Carcinophyllum Kirsopiana*, showing the external aspect of the corallum. Lower carboniferous, Arbigland, Dumfriesshire.

,, 7A.—A transverse section of the same, natural size.

,, 7B.—A longitudinal section of the same, natural size.

PLATE III.

Fig. 1 and 1A.—*Protocyathus Verrillii*, natural size.

,, 2.—*Protocyathus Dalryances*, natural size.

,, 3.—*Protocyathus serratus*, natural size.

,, 4.—*Protocyathus plicatus*, natural size.

,, 4A.—Showing the interior of the calice of the same.

,, 5 and 5A.—*Protocyathus contortus*, natural size.

,, 6 and 6A.—*Protocyathus spinulosus*, natural size.

,, 7.—*Protocyathus elegance*, natural size.

,, 9 and 9A.—*Protocyathus pachytheca*, natural size.

,, 10 and 10A.—*Protocyathus quadralamellum*, natural size.

,, 8.—*Pyrgia Labecha*, Edwards and Haime, natural size.

,, 11.—*Thysanophyllum orientale*, Nicholson and Thomson, a transverse section, natural size. Lower carboniferous, Aberlady Bay, Haddingtonshire.

,, 11A.—A longitudinal section of the same, natural size.

,, 14.—A transverse section of a larger variety of the same, natural size.

,, 14A.—A longitudinal section of the same, natural size.

,, 12.—*Thysanophyllum minus*, Nicholson and Thomson, a transverse section, natural size. Lower carboniferous, Peter's Hill, Bathgate, Linlithgowshire.

,, 12A.—A longitudinal section of the same.

,, 15.—*Cyathophyllum echinatum*, a transverse section, natural size. Lower carboniferous, Gateside, Beith, Ayrshire.

,, 15A.—A longitudinal section of the same, natural size. D and C points to the interlamellar stria passing downwards and outwards.

,, 16.—*Lonsdalia rugosa*, M'Coy, a transverse section, natural size.

XIX.—*The Physiology of Sleep, with a consideration of the different Theories propounded as to its cause, and the suggestion of a new view of the Subject.* By John Glaister, M.B., L.R.C.P. and S., Edinburgh.

[Read before the Society, April 14th, 1880.]

In the many physiological works hitherto published, the student experiences a difficulty in understanding anything on the subject of Sleep, owing to the meagre consideration bestowed upon it. Whether the subject, to the authors, seems of such minor importance as almost to be dismissed in a word; whether the subject is of such vast importance as to entail more space in its consideration than could be allotted it in such books; or whether the subject is surrounded with such difficulties, experimental or otherwise, it matters not: sufficient for me to note the fact that so very little attention is devoted to it that the younger body, and, to a greater degree, the older body, of students are left almost in total ignorance of the subject.

Even in Dr. M'Kendrick's work on Physiology the subject is dismissed in a few sentences. On looking over a great portion of the literature of the subject, one is met *ad limine* by the fact that it is *not* one of minor importance, since many theories have been advanced as to its cause; and I think it imperatively necessary that we should at least form some idea as to its causation in order to rationally attempt its restoration when absent.

That the theories propounded have been many and diverse, even opponent, it will be my duty in the present paper to show. Suffice it to say, that doctrines so contrary as congestion of the brain and anæmia of that organ, superabundant presence of carbonic acid gas in the brain, and the under-supply of oxygen, are to be met with.

Sleep has been an institution since the origin of animal life, and will only cease with its dissolution. From the lowest animal *with* a brain, to the highest in the order of being—man—it is indulged in, and in order to adequately play their several parts in the economy of the world is it a necessity of their life.

The term Sleep has been, says Carpenter, in Todd's Cyclopædia of Anatomy and Physiology, "employed to designate that state of suspension of the sensory and motor functions, and which may be made to give place to it by the agency of appropriate impressions upon the sensory nerves." It is therefore a normal abatement, an entire cessation of sensorial impressions upon the mind, requiring an absence of everything calculated to stimulate the thinking and reasoning faculties, with a cessation of nerve-sensation from periphery to centre and from centre to periphery.

Man is said to be sleepy when the stimulus of the day, with its thousand pleasures, harassments, pains, and anxieties, ceases to have effect upon his motor and sensory nerves, when the usual exertion gives place to a liking for quiet and rest, and cessation of mental action.

We all, I doubt not, appreciate the beneficial effects of sleep, and, I presume, we are all alive to the necessity for it. It is necessary that we should sleep to enable the brain, exhausted by the thought of the past day, to repair its wasted energies for another encounter in the battle of the world.

Cullen—an old physiological writer—with many others of his day, held this opinion on the necessity for sleep—"that the brain is a secreting organ which secrets a fluid necessary to the functions of the nervous system; that the fluid is alternately exhausted and recruited, and thereby gives occasion to the alternate states of sleep and waking."

The period for sleep, speaking generally, is that time intervening the sunset and the sunrise. Milton graphically describes the situation:—

> "Now came still evening on, and twilight grey
> Had in her sober lining all things clad,
> Silence accompanied; for beast and bird,
> They to their grassy couch, these to their nests
> Were slunk."

Every rule has its exception, so this, as any other, has *its* exceptions, since, in the zoological world, we have the moths of the Lepidoptera and the owls of the Aves carrying on their flight in the night time—resting, however, when general nature is astir.

Sleep, comparing it with active life, is just semi-death, since man, under its influence, receives no impressions from the outside world, while only the organic actions of the heart, breathing, and peristalsis of the intestines, although perfectly involuntary, go on unremittingly—the animal functions, all the while, being in abeyance.

Cullen, quoted before, in the third edition of his Institutes of Medicine, says that during sleep there is a state of collapse, aggravated in the state of syncope, and still more greatly aggravated, "still more complete and irrecoverable in the state of death;" and Pflüger regards the conditions of apparent death and sleep as parallel to each other.

Quoting from a leading article on Dreams in the *Lancet* of March 20, 1875, p. 413, we find that "the characteristic of the state of sleep is the absence of all outward sign of consciousness and will, which are seemingly withdrawn from all connection with the organs of sense or with those of motion, by which their existence could be manifested."

That there seems to be during troubled sleep—that is, sleep attended by dreaming—an intellectual activity, no one can doubt, and even that activity present to a great degree, with this difference, however, that the will is in abeyance, making again the difference in the active waking and sleeping dreamy states, that in the former we have intellectual activity plus will, in the latter the intellectual activity minus will; whereas the difference existing between healthy sleep and the waking state is one of intellectual activity governed by the will, in the latter condition, and the absence of these in the former.

It may be asked, however, why should muscular movements take place during sleep, if unattended by intellectual activity and will, since these movements have in them the evidences of well-directed and rational purposive effort? Just for the same reason it may be answered that the same muscular movements may take place in the lower limbs, even though they be paralysed, through some special lesion in the spinal cord at a point above that from which the nerves supplying the limbs take origin. The physiological reason answers for both—That in the former, as in the latter, there is no message conveyed by the affected sensory nerve to the motor tract further than the spinal cord, and that the actions so induced are reflex, involuntary, and automatic. It has also been said that during sleep the higher nerve-centres lose control over the lower, thereby allowing of freer exercise of function during that condition; "that the action of the lower centres is restrained by the inhibitory influence which the higher centres exercise over them, and during sleep that is withdrawn."

It will next be my duty to consider those causes which predispose to sleep. Carpenter, in his Human Physiology, sixth edition,

p. 592, says that one of the strongest predisposing causes to sleep is "the absence of sensorial impressions. Thus darkness and silence usually promote repose; and the cessation of the sense of muscular effort which usually takes place when we assume a position that is sustained without it, is no less conducive to slumber." While Cullen, in the book before mentioned, enumerates as some of the remoter predisposing causes of sleep "cold, the absence of impressions, attention to a single sensation, or to sensations that have no consequence in thought or action; the finished gratification of all vehement desires, sedative sensations and impressions, evacuations, relaxation, and any violent, frequent, or long-continued exercise of the animal power."

Having so far understood, then, in a *general* way, what predisposes to sleep under varying circumstances, we shall proceed another step further by inquiring into the *special* requirements for the procuration of healthy sleep—requirements, I may add, of which we all endeavour to be possessors. They are almost essential to procuring sleep, although exceptions could be easily pointed out.

I. Everything that tends to muscular or mental fatigue.

II. Quietness and rest.

III. A position of muscular inactivity.

I.—EVERYTHING THAT TENDS TO MUSCULAR AND MENTAL FATIGUE.

We have only to look around us on every side to see the intense muscular activity and mental celerity which characterize our day and generation; and living, as we are, at a high rate of pressure, we attempt compressing into the short space of, let me say, twelve hours, what, in our commercial world a century ago, required days to accomplish, but by the aid of rail, electricity, steamboat, and postal systems, we truly have put a girdle round the world, although, perhaps, not so quickly as *Puck*, of Shakespeare's "Midsummer Night's Dream," said he would.

These labours entailing muscular action do always necessitate more or less of the mental, but varying in degree as to the kind of labour engaged in; but the converse does not hold so true, as we have, in our literary men, poets, historians, novelists, artists, and other head-workers generally, a preponderance of the mental action over the muscular—a maximum of the former, a minimum of the latter.

Another point to be taken into consideration in relation to man as an individual, is, that men being differently constituted and gifted by nature with different capabilities of endurance, the amount of labour producing fatigue in one man will be as nothing to another man. But that affects man as a species very little, as the amount of waste produced by whatever amount of work engaged in must be made up, and as rest must follow as a corollary to action, so do muscular and mental fatigue become predisposing causes to the production of sleep.

II.—Quietness and Rest.

It is perfectly easy to appreciate that one of the necessities for obtaining sleep is quietness, so that nothing should excite or stimulate, and keep the mind alert; and this is borne out by the obvious withdrawing of ourselves to the quiet of the bedroom, there to be secure from noises so far as we can. But though that be the case, we also know that persons who live 'neath the perpetual clang of the hammer, the roll of machinery, the clashing fall of water, and the glare of furnaces, accustom themselves—since habit is second nature—to drop into the arms of slumber as readily as those habituated to quietness, and who, besides, speedily would awake were these conditions to cease. These, too, with the dropping of water, the moaning of the winds, the noise of breakers on the shore, the continual traffic of railway trains, the ticking of the clock, and other like continuous noises, have by their "mechanical repetition" a soothing tendency, and act in an analogous fashion to the lullaby which the fond mother sings to her babe to soothe it asleep.

Men have, on the other hand, been known to sleep while "the blast of war blew in their ears," when cannons boomed and shells shrieked; have also been known to sleep in the "crows' nest" at the mast-head, although the stiffest gale was blowing; and they have been known to sleep while marching, and even while riding.

Sleep, then, is not impossible in situations having for their surroundings, conditions as opposite as those depicted.

III.—A Position entailing Muscular Inactivity.

This is a condition in which we participate when we try to sleep, and that not only by reason of habit or hereditary instinct, but through the working of physiological laws.

To one who can thoroughly appreciate the *modus operandi*
the abolition of volition and nerve-influence during sleep, and
e necessary continuance of that same during the hours devoted
that end, the reason of this factor will at once make itself
ain.

The extension of messages through the nerves to the brain—
om periphery to centre—stimulates the nerve-matter of that
gan, and, in most cases, causes an emanation of volition, neces-
rily inciting such an excitement of the mind as will produce and
ep up the waking condition; so that any position which will
tail nerve-influence from the brain to the muscles is not that
sition most suitable for obtaining sleep. As muscles by their
tion, and especially by purposive action, cause such an extension
nerve-influence from the brain, which action, let us say, requires
e muscles being kept in a state of contraction in order to support
e attempting sleeper in his assumed position—there will neces-
rily be required, primarily, an act of volition to assume the position,
d, secondarily, to sustain it, which render the mind active, and
obviates one of the principal factors for obtaining sleep—viz., an
sence of voluntary effort.

This condition entailing muscular inaction, then, will be readily
en to be necessary, since a person trying to obtain sleep in any
sition rendering voluntary muscular exertion necessary, perhaps
rough the continual fear of falling, together with the extension
motor nerve-influence from brain to muscle, renders that organ
nscious of the extended nervous action, and so diverts it from
ep.

That this is absolutely necessary may be denied by many, and
ndreds of examples may be at once put forward as proving the
posite. It is to those individuals granted at once, that in the
ost peculiar positions, and even in those requiring severe, con-
ued, and co-ordinated muscular action—such as riding on horse-
ck or in walking, as instances are repeatedly observed of soldiers
eping in forced marches—do we find instances of refreshing
ep being obtained; but these are exceptions to the rule, and are
e result of such severe and prolonged muscular exercise that the
ts have so far become automatic, and necessitate no extension of
luntary effort.

But to return to our datum. It is to attain this end of muscular
action that we adopt the horizontal posture, since then the whole
uscular system is relaxed, put in such a position that no voluntary

effort is required, and consequently is there the best chance of getting sleep.

Hunter noticed long ago that, during sleep in the lower animals, there was a tendency for the body to be curled up in the form of a ball, and he inferred from this that the flexor muscles of the body were stronger than the extensors, and caused the animal to assume that position.

We will now proceed a step further, and inquire how the senses comport themselves when we go to sleep.

It has been established that all the senses do not fall asleep consentaneously, but rather the one before the other, and that in regular order.

Sight goes first, since naturally the first thing we do on seeking sleep is to close the eyes, with the intention of obviating the impression of objects upon the retina to be carried to the brain, and the extension of nerve-influence from the brain to the optic nerve.

Taste goes next, then smelling, then hearing, and, lastly, touch follows suit.

The latter sense is the most acute, even during sleep, and is awakened most readily. It is said, too, that certain parts of the body sleep before others, always commencing at the point furthest away from the centre of nervous action. Hence the reason why cold feet should be avoided on going to bed. The sensation of cold feet, after a hard night's studying, is well known to all students; and should they keep cold long after being in bed, we soon find that they are a great source of discomfort and uneasiness, rendering sleep thus far impossible, since their condition involves consciousness on the part of the brain.

Having, then, considered the factors which go to put the person trying to obtain sleep in the best possible condition for its obtainance, it will next befit us to show what changes occur in the different organic functions during sleep—of course, premising for the time being that sleep has been procured.

I. In the heart's action.
II. In the respiration.
III. In the bodily temperature.

I.—In the Heart's Action.

During the active waking condition the number of contractions of that organ differ in number as to the amount of exercise or excitement experienced by the person, but varying from 60 beats per minute to double that number, while during sleep we find that that organ rhythmically contracts relatively slower.

That the position of the body affects the number of contractions per minute no one doubts. M'Kendrick says, speaking of the pulse, which is the index to the heart: "It is more frequent in the erect than in the sitting position, and quicker than in the recumbent posture." This is somewhat dependent upon the absence of muscular action, and the less amount of blood required to be sent in the same time to the different tissues in that condition, the absence of any excitement, the healthy condition of the organs of the digestive system, and, *a priori*, a healthy condition of the heart itself.

Again, it seems that the heart contracts much less frequently as night advances, the diminution in frequency being more regular and more rapid in the evening than in the morning.

II.—IN RESPIRATION.

During sleep there is a lessening in the number of respiratory acts, which so far is regulated by the number of heart's contractions in order to sustain the pulse-respiration ratio, and also because a less quantity of oxygenated blood requires to be sent to the quiescent frame.

Granting, then, that respiration is slower during sleep than activity, there must be a less amount of the respective gases, oxygen and carbonic acid, inhaled and exhaled. Supposing that with the pulse at 80 we have the number of respirations at 20 during activity, it stands to reason that there will be less oxygen inhaled while the pulse figures 60 and the respirations 15, things being equal. Again, there is less CO_2 evolved. Kirke says that "during sleep there is a *considerable* diminution in the quantity of this gas evolved." Besides this fact we must also note another—that different temperatures affect the quantity; the colder it is the more CO_2. Letelier says "that the higher the temperature of the respired air the less is the amount of carbonic acid exhaled into it, whilst the nearer it approaches zero the more does the CO_2 increase;" while Clelland, in his Animal Physiology, p. 144, corroboratingly remarks: "It (CO_2) varies according to a great variety of circumstances, being increased by *cold*, by food, and most of all by exercise; while warmth, fasting, rest, and *sleep* diminish it."

The reason why I enter so particularly into this point will be more appreciated by you when I consider one of the theories of sleep—viz., the carbonic acid gas theory.

We have still to consider our third point:—

III.—THE CHANGES THAT OCCUR IN THE BODILY TEMPERATURE DURING SLEEP.

During normal activity the temperature of the blood varies between 100° and 102°F., and we know that the normal bodily temperature, as obtained from mouth and rectum, is from 98°5 to 99°5·F.

But during sleep we find that there is an appreciable lowering of the temperature of the body, and that to the extent of 1° to 1½°F.

Kirke has it: "During *sleep*, hybernation, and other states of inaction . . . the temperature is proportionately diminished;" while Dr. Cowden Thomson found in his experiments that "in those hours wherein sleep usually takes place—namely, from 12 p.m. till morning, particularly in summer—*the heat falls one degree*;" and the illustrious John Hunter, in his writings, remarks: "When a man is asleep he is colder than when he is awake; the difference, in general, I find, is 1½ degrees, more or less."

When, then, we note the fact that during sleep the temperature falls 1°, we must look for the reason in the conditions of the other functions, circulatory and respiratory.

Knowing, therefore, that for the obtaining of healthy sleep there must be an entire absence of volition and consciousness on the part of the brain, and observing the phenomenal changes in the circulation, respiration, and temperature of the body, it should next be our duty to consider how it is that sleep should naturally be sought for in the hours of darkness, when all the world is quiet and still. The reason is to be found in the simple fact that during these hours causes for activity are removed. Before the days of artificial lighting were in vogue, the humbler classes universally went to bed when the natural light of day had ceased to be present, and, if they indulged in an extra wakeful hour, the humble rushlight, the splinter of pinewood, or the fragment of coal, provided the source of light. But civilization has changed all that, and unhappily not for the better. Certain it is, however, that at whatever time we court sleep, nature demands that duty of us, and compels us to meet it. The temperaments of men, granting there are such (but upon the existence of which some are wont to lay little stress), influence the amount of time devoted to sleep—the plethoric requiring more than the sanguineous; and some men, as Wellington, are proverbially short sleepers, while others can want it for a considerable time, as the celebrated French general could when required, but make up for it by lying in bed for a week.

It is also a fact that we require more sleep in the winter season than in any other.

On such a subject as we are now considering, involving as it does an immense amount of hypothetic reasoning, we need feel no surprise, on looking into its literature, that very many theories have been started as to its probable cause.

Among the earliest of them we find:—

I. The depression of the laminae of the cerebrum. Then later on:—

II. Pressure of blood on the brain, or venous congestion.
III. The mobility of the nervous fluid (Cullen).
IV. The carbonic acid gas theory.
V. Carmichael's nutritive theory.
VI. Atkinson's theory—lessened rate of circulation.
VII. The anæmic theory.
VIII. Pflüger's theory; and
IX. Rhythmic nutrition theory, as suggested by myself.

Let me discuss these *seriatim*, as briefly as their apparent substantiality will allow.

I.—THE DEPRESSION OF THE LAMINAE OF THE CEREBRUM.

This is a theory unworthy much consideration, since we know that, on depression of any part of the cranial vault sufficient to compress the brain, a condition of things is brought about—coma—which we all know to be a different thing from sleep, and easily recognized from it. Again, the adult calvarium is so firmly fixed, is so immovable, that it is impossible for it to collapse, even in the most fractional degree; so that this theory can only have been adduced by the erroneous interpretation of the two conditions—healthy sleep and coma—and an ignorance of their physiological cause.

II.—PRESSURE OF BLOOD ON THE BRAIN, OR VENOUS CONGESTION.

This theory has been held by many physiologists eminent in their time, and we need only mention the names of Haller, Hartley, Marshall Hall, Carpenter, in his earlier writings, Sir Henry Holland, Dickson, Sieveking, and Henry Lewes, to show that at one time, and even yet, it was a doctrine held in high esteem. Nay, there is even now in the writings of one of our local physiologists a tendency shown to encourage this theory.

Fleming, in the *Glasgow Medical Journal*, July, 1877, in an article on "The Motions of the Brain," obtained by Marey's graphic method from patients, a portion of whose cranial vault had been lost through accident, obtained results differing from MM. Salathé and Mosso, fellow-workers in the same field, which pointed to a congestion of the brain obtaining during sleep. He adduces tracings to prove his point. In a tracing from a lad, wide awake, the aortic notch is seen to be well marked, which, however, to be noted is "nearly absent" in the sleeping condition. But, as the writer himself hints the possibility of some inexact application of the cardiograph, perhaps the tracings may lose a little of their value. But it is only fair to the writer to add that every possible chance of error was avoided as much as possible. Macnish, by Hammond, is said to be in favour of this theory, and what he says at p. 11 of his Philosophy of Sleep is as follows:—"Full-bodied phlegmatic persons are actually much better sleepers than others. First, from the greater pressure of blood on their brain; second, from their natural disposition being less airy, sensitive, and irritable." But further on he says—"*In sleep there is a less determination to that organ than in the waking state.*" Therefore would I incline to rank him among those who favour the Anæmic theory. Marshall Hall's idea of the cause of the congestion was, that there were certain muscles which, by pressing on the veins of the neck, prevented the venous return. Dr. Cappie, of Edinburgh, in a small brochure published on this subject, gives it as his opinion that this is one of the factors of the cause of sleep, but dividing the honours with two others—viz., a modified nutrition, and a weakness of the capillary circulation.

Unfortunately for the holders of this theory, the preponderance of experimental observation has shown the blood condition of the brain to be entirely opposite. Of this evidence more anon.

III.—CULLEN'S THEORY.—THE MOBILITY OF THE NERVOUS FLUID.

This theory hangs upon the fact that at that time the brain was considered to be a secreting organ, having for its function the secreting of a so-called nervous fluid, which, being dispersed throughout the body within the nerve-fibres or tubules, gave as result the motor and sensory functions; and upon the generally known fact, that any gland, after prolonged action, secretes less fluid and requires nourishment and rest to re-establish its secreting vigour. So in the case of the brain was there less nervous fluid secreted and less force generated for the requisite rapidity of transmission of that nervous fluid—consequently stagnation of the current ensued. He says "he is disposed to believe that these states of sleeping and waking depend upon the nature of the nervous fluid itself capable of becoming more or less moveable."

We now know that the doctrine of the brain being a secreting organ, and its secretion a nervous fluid, is a thing of the past; but this fact we also know, that the more prolonged and severely sustained in action a nerve is, so much less does its quickness of conductivity become. Nervous force in man normally is about the rate of 97½ feet per second, as calculated by Helmholtz and Schlieske, and by analogy we infer that a tired brain will transmit nervous force in a less degree; and conversely, a tired muscle will be the more likely to cause less response on the part of the brain, since Ferrier has so far proved that the nervous matter supplying a muscle or set of muscles with its energy is to a greater or less degree a circumscribed portion, and therefore the more readily exhausted. That there is a stagnation, or more properly, an abeyance of the nervous force during sleep, we are ready to admit—not, however, through the agency of a nervous fluid; but to say that that abeyance of the nervous force is the cause of sleep is about equal to saying that the result and cause are the same—an inference which nobody will admit.

IV.—THE CARBONIC ACID GAS THEORY.

Hibbert, in his Theory of Apparitions, quoted in Milligan's notes of Majendie, gives us the best idea of the theory, and we will therefore quote what he says:—

"In sleep, it is said, the breathing becomes slower, less carbon is given out, and consequently some of its compounds—carburetted hydrogen, or carbonic oxide, or carbonic acid—accumulate in the vascular system, and in the course of the circulation is supplied to the brain. But all these gases are notoriously soporific, and will avail to keep the person asleep. But how is he first put asleep or even rendered sleepy? Nothing is plainer, reply our theorists. The exhaustion of the diurnal stimulation and exercise reduce the irritability to that point where the stimulus imparted by external objects is just sufficient to keep him awake. Then the man is said to be sleepy; and it is all one whether we add a little to the exhaustion by a sedative, or subtract a little from the stimulus; in either case the equilibrium is overset, the excitement of the external world no longer balances the excitability, and of course is not felt—in other words, the man is said to be asleep. Now, before actual sleep, both pulse and breathing are lower from the previous exhaustion; therefore carbon is accumulated in one or other of its soporific combinations; but the sedative effect of this, added to the previous exhaustion, easily depresses the excitability below that point where mundane irritants can affect the body. It lulls him to sleep. . . . .

"Again, it may be asked how, since the carbonic sedative goes on increasing, does the sleeper after a certain period awake? Ought not his sleep to grow deeper and deeper? Quite otherwise, it is answered. During sleep the nutritive process is busily at work to repair the irritability lost throughout the day; and being now undisturbed by the external world, soon accomplishes its task, but in such a manner that the sum of the excitability, old and new, is made more than necessary to counterbalance the sedative influence of the gas, becomes therefore again available to the external world which stimulates it and is perceived."

It is granted, I presume, that healthy blood contains always a certain admixture of carbonic acid gas, and that this is lessened or increased according to the rate of respiration, food taken, its amount and kind, and hour of the day; and it is an established fact that the quicker the respiration the less CO_2 is there in each individual respiration, but in the aggregate of the minute there is a larger quantity of that gas evolved than if the respirations were slower.

Let us look if the lungs corroborate any of the above statements.

Vierordt says that, "with six respirations per minute, the quantity of expired CO_2 was 5·528 per cent.; with twelve respirations, 4·262 per cent.; with twenty-four, 3·355 per cent.," and so on, decreasing in amount in each individual respiration as their number per minute increased, but increasing in the aggregate amount because of the greater number of respirations executed in the minute.

Kirke says, "By diminishing the frequency and increasing the depth of respiration the percentage proportion of CO_2 in the expired air is diminished, being in the deepest respiration so much as 1·97 per cent. less than ordinary breathing."

Now, it is during sleep that we have the deepest respirations, and so we may safely say there is in each respiration 1·97 per cent. less CO_2 evolved during that time than during wakefulness. Now what becomes of this 1·97 per cent.? Whither is it disposed?

Milligan has it that "Mr. A. Brande has lately demonstrated that every ounce of blood contains at least two cubic inches of CO_2, and Drs. Prout and Fyfe that the quantity exhaled from the lungs varies according to the food and drink, and time of the day; but as both the carbon passed off by the lungs and the CO_2 circulating in the blood must be furnished by the same chyle, it is probable that when the pulmonary carbon is diminished the sanguineous carbon or proportion of carbon is proportionately increased. Now, the twelve hours of the day in which the carbonous excretion is least fall between nine at night and nine of the morning—the most natural season of rest; and it seems quite obvious to conclude that it becomes so merely on account of the increased quantity of carbonic acid retained in the system. Infants and hybernating animals," it is added, "confirm the same view, since the former possess only carbonated blood, the latter having a slower respiration, incapable of giving out the necessary quantity of carbon. Hence both sleep soundly. . . . ."

This theory at first sight looks extremely ingenious and plausible, and would seem perfectly to satisfy the casual observer, but upon examination of its physiological data more closely, we will, I think, find very good reasons for considering otherwise and differing.

Upon entering, then, into a consideration of the foregoing theory, it will first be our duty to, as it were, analyse it, and see upon what grounds the theory may be supported, and what facts can be adduced in proof thereof. I think, therefore, there is only one fact which, superficially however, looks to support it, and that is the lowering of the temperature during sleep, which, according to observers generally, ought to increase the quantity of CO_2 evolved, whereas, on the opposite hand and in the face of facts, we find it *diminished very much.*

The whole theory, resolving itself as it does into an accumulation of CO_2 in the blood of the brain, as supplied in course of circulation during the sleeping hours, seems to have that fact so far in its favour, as it would seem casually to prove the existence of the non-evolved surplus of CO_2 in the body generally, and in the brain particularly, so far as it is said to produce sleep according to our theorists. But is there not a fallacy in the inference that "when the pulmonary carbon is diminished, the sanguineous carbon, or proportion of carbon, is proportionately increased?"

What facts can be led against this inference to bring about its legitimate refutation, and if there are, what are they?

First. That the deeper the respirations—a state of things which happens during sleep—there is less carbonic acid gas evolved. This is proved by Kirke's statement, already quoted.

Second. There is a distinct diminution in number of respirations during sleep, which, as I have before shown, necessitates the aggregate amount of CO_2 evolved per minute being less than if the number of respirations were greater, as during activity—that is to say, supposing during sleep we have 15 respirations and during wakefulness 20—*cæteris paribus,* there is a proportionately less amount of CO_2 evolved, collectively, during the former period than the latter.

Although the lowering of the number of respirations per minute would seem to incline favouring the foregoing theory at sight, since it might be argued that this was a condition of things specially brought about to favour the increase of "sanguineous carbon," still its *raison d'être* arises from another cause, to be found in our next statement.

Third. During sleep, the heart contracting less frequently than during activity, there is consequently a diminution in the rate of the systemic and pulmonic blood-flow, the blood coursing the vessels very much slower, so that there must be less oxidation or combustion of tissues going on. We might put our argument differently, thus:—During sleep the whole voluntary muscular element is quiescent, consequently there is not that waste arising from activity, there is less tissue-combustion, and the requirement of the blood-supply moderated. All of which things tend materially to affect the amount of CO_2 evolved, and that to a considerable extent of diminution.

Following upon these facts, we have the less demand on the part of the tissues for their supply of oxygen from the outside air, and the tissue respiration, if I may so term it, is modified according to the tissue requirements.

Fourth. It is well known that in ordinary easy respiration there is a larger quantity of oxygen inhaled than is required with the carbon of the tissues to form CO_2, and it is also known that a part of this extra oxygen is given out as sensible and insensible perspiration by the glands of the skin. Now, during sleep there is generally a greater activity of the dermal functions than during wakefulness, consequently more oxygen in combination will thus be employed.

Macnish on this point says, "Although there is no increase of heat on the surface of the body, *the perspiration is augmented*, which, according to Sanctonus, a person sleeping some hours undisturbed, will perspire insensibly as much as one awake." Carpenter also corroborates this fact.

Fifth. Baker expresses me here when he says—"It is to the accumulation of CO_2 in the blood, and its conveyance into the organs that we must, in the first place, ascribe the phenomena of asphyxia."

So that, were sleep produced by the cumulative action of CO_2, whenever we went to sleep this asphyxiating tendency would begin, and cause us to sink into coma, and latterly die. This, however, is not the case, as we know from practical experience, in the progress of "nature's sweet restorer."

To sum up. That the decrease in amount of CO_2 evolved during the sleeping hours, then supposed by our theorists to be the cause of sleep, is only the result of physiological laws during that state, I take it I have clearly shown, since nature, pattern to political economists, faithfully regulates her laws of supply and demand. So that, although there is a decrease in the "pulmonary carbon," it is impossible to conclude, other than by a very shallow inference, that the "sanguineous carbon" is increased.

But there is a side-question crops up now, which it would, perhaps, be well to speak of at this stage.

Why is it, it may be asked, that one after dinner feels drowsy and sleepy? Why the so oft indulgence in "forty winks" at this time? True it is, that food taken increases the quantity of CO_2 evolved from the lungs; but I answer, granting that one's digestive system be in good repair, there is no reason why one should feel drowsy; and, in reply to the "forty winks" question, I would be inclined to answer, 'tis the outcome only of an indulgent habit, not at all called for by nature, and is never so refreshing as sleep during natural hours is.

The main reason for its production, not speaking of the effect of alcoholic drinks partaken with the food, seems to be centred in the fact that, after dinner, we place ourselves in conditions predisposing to it—such as an abeyance of voluntary muscular action, a renunciation of will and consciousness, a situation of quiet, &c. Some have, however, attributed the sleepy feeling obtaining after meals to be due to anæmia of the brain brought about by a partial diversion of the blood from that organ to the organs of the digestive system, in order to provide materials for the glands, whose juices act on the food for its perfect digestion.

We have to consider next the fifth theory:—

V.—CARMICHAEL'S NUTRITIVE THEORY.

Carmichael was Macnish's opponent on the question of sleep.

The best condensed explanation of his theory I give in the words of his reviewer, as found in the *Med. Chirurg. Review*, vol. xxiii., 1835.

The reviewer remarks—"The absorbents and secerning (blood) vessels never remit their offices—those carrying off the old particles from every point of the frame and these depositing new ones in their place; the absorbents being most busy with the muscular fibres which are most exercised by labour, or the nervous fibres most exercised by the operations of sensation, volition, and thought. Yet these fibres, so exercised, are always the strongest and most powerful of their kind in the frame; the secerning vessels must, therefore, be equally busy in restoring new particles in the place of the old, or during certain intervals rather more busy, because more are restored than are taken away, as is proved by the increase of size proportioned to the occasional or habitual use of the parts. Yet it is evident that it is not during the moments of exercise that the great mass of new matter is deposited, otherwise the muscular and nervous fibres in question would go on thickening and strengthening, the longer the exercise of labour and thought was continued; and this, we know, is contrary to fact:—Fatigue ensues and rest is necessary, and during that rest it is probable that the secerning vessels, though always depositing new particles, deposit much more, or the absorbents remove much less, than at other times.

"By rest I mean a mere cessation from labour, and such rest is not sleep. The large mass of new particles deposited on the muscles cannot effect their tough and insensible fibres by any striking phenomenon, but when such a mass is deposited on the delicate, tender, and sensible structure of the brain and nerves, how different must be the effect. If small in quantity, and while these organs are in a state of active energy, it may be hurried unobserved into the existing activity of the living matter, but if large in quantity, and while these organs are resting from their labour, can it be that the extraneous and unassimilated mass does not press its increasing weight on their fragile machinery, and produce an effect *something like* the pressure of the over-swollen blood-vessels, but natural, necessary, and healthful—the paralysis, not of apoplexy, but of sleep?

"While the incumbent mass thus paralyses the encephalon the body is powerless; there is no voluntary motion, no perception, no thought, no dream.

"But when the assimilation is complete in any one of the organs of the mind then thoughts arise; but there is no perception until the assimilation is also complete in one or more of the organs of the senses; until then the simple current of our thoughts constitutes an ordinary dream." He then broaches the hypothesis that protracted sleep is the result of a superabundant and incessant deposit of new nutritive particles which continue the paralysis past the usual term of healthy slumber, and goes on to further remark "if it should be asked, how can the same cause operate in different ways? How can the assimilating process at one time cause sleep and at another not cause it? How can it, though unremitting in activity, at one time paralyse the brain and nerves, and at another enliven and invigorate them? He sagaciously adds, these questions are difficult, and the more difficult because in the material world we can find no object wherewith to compare and illustrate the phenomena of mind. The element of fire must suffice on the present occasion where no better ligament of analogy between things so different can be had.

'Nutritur ventis, ventis extinguitur ignis,
Levis alit flammas, grandior aura necat.'

"If a fire burns clearly, brightly, and fiercely, still it requires a constant supply of fuel to keep up its intensity, and replace the solid particles expended in combustion. A small quantity frequently added, so far from paralysing, increases the activity of the fire; but when that activity is exhausted, when the very energy is exhausted, when the very energy of the flames, like the exertion of a powerful mind, has wasted away the substance on which it fed, and these flames sink enfeebled, and the fire is diminished and dull, if you heap over it a heavy mass of fuel the flames are smothered, the activity ceases, the element sleeps. Hours are required to extend the vivifying influence to the new matter; at length the increasing warmth pervades the whole mass, the assimilation is complete and the smallest incitement stirs up again all the energies of the furnace. If no aliment be supplied to the glowing mass, it will burn out, like an overworked brain in similar circumstances; while too great a weight of fuel cast on the exhausted hearth overwhelms the expiring embers, and the result is the slumber of death not of sleep."

[The above theory may be further examined in the *Phrenological Journal*, June 1, 1836.]

The reviewer of the above statements adds rather facetiously, "If this image of death be occasioned by the deposition of large masses of new matter on the delicate organisation of the brain and nerves, inducing 'the paralysis of sleep,' it is curious how the bite of a flea or bug will often disperse all these depositions, and start us into wakefulness."

Let us now consider the theory.

It seems to me to be developed upon a misunderstanding of the laws of nutrition which are embraced in four factors—I. A right state, composition and condition of the blood by which the parts are to be nourished; II. A regular supply of that blood; III. A certain condition of nerve influence; and IV. A healthy state of parts themselves, in order that they may take from the blood these elements which best afford them nourishment.

Mainly, however, Carmichael's theory violates the second of the above laws—a regular supply of blood,—since he assumes that there is, at times, an irregular supply to the tissues, giving them superabundant nourishment, and as his idea of that state upon the brain causes a comparative paralysis of function by its pressure.

He assumes, in short, that during sleep there is a superabundant supply of nutritive material given to the nerve fibres and cells of the brain, which impedes the function of that organ in so far as it prevents acts of volition, sensation, or ideation, acts as a clog upon that organ and arrests its working.

We grant that, for the waste of an exhausted brain, in so far as in function the vitality of some of its cellular elements is impaired, if not destroyed, there must be a corresponding amount of nutritive material supplied to it to recuperate it; but I cannot see my way to grant that, in the production of such nutrition, a superabundant amount should be supplied, since it gives more than nature demands, and is consequently unneeded.

He takes it for granted that, only at times, &c., during sleep, there are more of the " new nutritive particles supplied " than are taken away, as is proved, he adds, "by the increase of size, proportioned to the occasional or habitual exercise of the parts." Here he evidently means hypertrophy, such as ensues in the biceps of the blacksmith's arm from continued exercise. But this is a provision of nature to supply increased strength where increased and prolonged force is required. It is in no way analogical to the deposition of nutritive matter on the brain.

Cases of hypertrophy of the brain happen as do cases of other hypertrophied organs, but it would be a rash thing to conclude, in the case of the brain, that such a condition existed every time we sought our couch to sleep.

There is no other organ of the body so elaborately supplied with delicate blood-vessels for nourishing it as the brain, but still it falls under the same laws as other organs, in so far as so much waste, there must be correspondingly so much nutriment. No organ is at any time so loaded with nutritive particles that its action is impeded or arrested, but nature regulates the supply and the demand so correctly that as the waste is, so is the nourishment.

Organs, at different times and under differing existing conditions, require different supplies of blood, different quantities of nourishment. A man's muscles require more nourishment after prolonged exercise than they do when at rest, or comparatively so. So, too, when a brain has been tried by prolonged action, it requires more blood to sustain its energies than it would do when comparatively at rest, its functions being in abeyance. How is this brought about? By the third factor to healthy nutrition—a certain nerve-influence. Kirke says—" Any condition in these organs which causes them to need a different amount of blood, whether more or less, produces a certain impression on their nerves, and by these the impression is carried to the ganglia, and thence reflected along the nerves which supply the arteries, and these so-called vaso-motor nerves are again connected, through the medium of ganglia, with the fibres of the sympathetic system supplied to the organs nourished by these same arteries."

Hence, nature works methodically to supply the required nourishment, but never overdoes the matter, never overloads the brain, and so clogs and retards or arrests its function. Again, we may remark, since, according to our theorist, the brain in sleep is loaded with this superabundant material, we would naturally expect that its vessels would be more filled with blood than during activity, but how contrary do we find it? Anæmia during sleep is the condition found, not comparative hypervascularity.

The theory is beautifully worked out. That much must be said of it; but it is worked out on false premises, and consequently will not hold water.

We must still look elsewhere for light.

VI.—ATKINSON'S THEORY.

In vol. xvi. of the *Edinburgh Medical Journal*, pp. 109-113, Dr. Atkinson brings forth his theory, after having considered previously suggested causes of sleep, that it is due to *a lessened rate of circulation.*

I have had occasion, in an earlier part of this paper, to note that a lessened rate of circulation was due to the position assumed by the body when sleep was being courted, since the pulse-rate is found to be lowest in that position. Now, instead of assigning this lessened activity of circulation to be the proximate cause of sleep, I am rather inclined to consider it a factor falling in by the way. Certainly, excitement is one way of increasing the rate of blood-flow through the nervous system, and the absence of the causes of it, and more especially a state of mind devoid of will and consciousness as obtains during sleep, will oppositely tend to lower the blood-circulation rate; but to say that that is the ultimate cause of sleep I think an error. That there is always a lessened rate of blood-flow during muscular inaction, *cœteris paribus*, no one will dispute—a condition which exists during sleep,—but the lessened rate depends more upon the less amount of blood and nourishment required by the body than upon any other condition.

Doubtless, too, in that jaundiced condition of body which is often accompanied by intense drowsiness, do we generally find a owered pulse-rate, but that the latter condition is the cause of the omnolency I strongly dispute, since it is more likely due to the iliary elements circulating in the blood, producing by irritation, ontraction of the capillaries, and so causing comparative anæmia f the brain.

Again, also, a slight commingling of urea in the blood, produces omnolency in a similar way.

It is obvious that healthy sleep cannot be obtained while the ate of blood-flow is such as obtains during the waking state, and t can less easily be obtained if the circulation be in an excited ondition, but, I think, that the lessened rate of blood-flow-theory, ere broached by Dr. Atkinson, is only a result of the means sed to obtain sleep, and is by no means the chief factor in its production.

The next theory to be examined and discussed,

VII.—ANÆMIA OF THE BRAIN, IS ONE WHICH HAS MANY DISTINGUISHED SUPPORTERS.

Blumenbach, with whom the theory originated, Durham, Hammond, Ehrmann, Lauder Brunton, Salathé, Mosso, Dendy in "The Philosophy of Mystery," p. 283, Fleming of Cork, Donders, Kussmaul, and Tenner, are the names of some distinguished men who lend their names to a belief in this theory.

It will be my duty, firstly, to consider what physical proof can be adduced in its favour, and secondly, inquire into its physiological cause.

We will call the first witness, Blumenbach. The sum of his researches is to be found in Macnish, which I will quote:—"There is a case related by Blumenbach," says Macnish, "of a person who had been trepanned, and whose brain was observed to sink when he was asleep, and to swell out when he was awake, a proof of the diminished circulation in that organ during the sleeping state."

Then we will simply point out the results obtained by Mr. Durham, of Guy's Hospital, who trephined the skulls of dogs and removed a piece of bone therefrom about the size of a shilling; then removed the dura mater so that the brain was exposed and could be seen pulsating beneath.

A fuller account of his observations may be found by consulting Guy's Hospital Reports, III. Series, vol. vi., pp. 149-171.

He found that—

"I. Pressure of distended veins upon the brain, is not, as is generally supposed, the cause of sleep, for during sleep the veins are not distended.

"II. During sleep the brain is in a comparatively bloodless condition, and the blood in the encephalic vessels is not only diminished in quantity, but moves with diminished rapidity.

"III. The condition of the cerebral circulation during sleep is, from physical causes, that which is most favourable to the nutrition of brain tissue."

Fleming of Cork produced sleep by simply compressing the carotids of a person, while the same effect has been observed in patients in whom the same vessels had to be tied for disease.

Hammond's experiments on dogs, and observations on man, go to prove the existence of anæmia of the brain in the sleeping state.

The fontanelles of infants are observed to sink during sleep, showing also this condition.

Any one of you can realize this for himself when opportunity affords, and many a time have I watched the state of the fontanelles.

Allow me, still once more, to adduce an indirect proof of this condition.

Dr. Hughlings Jackson, in his opthalmoscopic observations of the retina during sleep, notices that he found "optic disc whiter, the arteries smaller, and the retina generally more anæmic than in the waking state."

These are physical proofs enough, then, to establish the fact that there is during sleep a comparative bloodlessness of the brain. Now for the physiology of it.

Before doing so, however, it would be well to consider the difficulty that meets us in determining exactly the condition [illegible] the encephalic blood-vessels after trephining the skull, since the vessels are more laid bare to atmospheric pressure than when naturally covered in by cranium and membranes.

This, by some, is said to invalidate the whole question, but [illegible] we look into the matter further we will find that the condition obtaining after such removal is one that we ought not to expect and therefore all the more conclusive in favour of the theory.

It is well known that if any part be supported by a bandage, let us say, so as to cause some compression of the vessels of [illegible] limb, and a part of that bandage cut out, thereby relieving the pressure, that the vessels in the exposed part tend to become congested. Well, apply this to the condition of the brain before and after experiment by trepanning. Before, the vessels are supported by the membranes surrounding the brain, as also by the bony structures outside all; after this support is gone, we would expect that the vessels would become congested, whereas we find they do not, but present the precisely opposite condition during sleep, pointing out more convincingly the real condition of the cerebral circulation. But although the encephalic vessels after trepanning are more subject to atmospheric pressure than in the natural condition, still the element of atmospheric pressure is not absent in the normal state. Aitken, of Netley, on this point, remarks, "that pressure is exerted on a large surface, composed of columns or tubes of blood in innumerable small curved vessels, which maintain through the scalp and diploë of the skull a direct communication with the blood within the cranium, and which is thus directly influenced by atmospheric pressure, while every anatomical arrangement of the parts within the cavity of the skull illustrates provision made to counterbalance the varying interchange of bulk between the solid and fluid contents of that cavity."

We now return to our physiology.

What causes the brain to assume a bloodless condition during sleep? If nourishment of tissue is the end in view why should there not be a larger than usual supply sent? The better to nourish the brain is the answer to the first query, and to prevent functional activity of that organ which would negative sleep is the answer to the second query.

I have so far considered this point before, but I may repeat here, and it is perfectly obvious to any one, that a part or organ, during normal function, requires more blood, hence more nourishment than it does when at rest, and as in the case of the brain, non-employed. And, paradoxically enough, it is the nervous system or rather a particular branch of it which has to deal with the regulation of the supply of blood to a part or organ.

An example of this regulation of blood-supply is to be found in the observations of Hughlings Jackson, since he found the blood-supply to the eye much less during sleep than during the waking condition, and that by reason of non-use.

Durham seeks to explain the cause of the anæmia thus (I quote from Atkinson's paper):—"The results of chemical changes in the nervous matter, which necessarily accompany the action of the brain—the debris, so to speak—impede the action by which they were produced, and a state of comparative anæmia follows."

From analogy, therefore, we are entitled to argue that the reason for the comparative non-conductivity of fatigued nerves is the same, since the products of disintegration impede their functional activity, at the same time pointing out that the tired organs, so to speak, require rest and nourishment. Anæmia of the brain, then, means a contraction of the blood-vessels, and the rotation of sleep and wakefulness involves periodicity of contraction. The next question we have to ask ourselves is—how is this periodic contraction brought about? The *modus operandi* is embraced in the paragraph quoted before, viz., from a stimulus originating in the sympathetic reflected to the vaso-motor nerves. But why say periodic in the sense of a fixed time? Why do the pains of labour repeat themselves and not, on the other hand, become continuous without intermission? Simply because the organ requires to resuscitate itself for fresh efforts, and, in the case of the brain, does the contraction come on because the organ has reached that point where rest and nourishment are required for resuscitation, and in order that it may be enabled again to perform its necessary work.

Habit influences the time allotted to slumber, and habit, so far, influences the periodicity, in the sense that at the proper time shall the vessels of the brain be put in that condition the better to allow of the necessary rest and nourishment to that organ. The periodicity is therefore regulated by habit, but more so by necessity.

But we focus this subject by asking ourselves the question—does the anæmia of the brain represent the proximate cause of sleep, or is it only the condition in which the brain must be put in order that *that* sleep be obtained, the cause, on the other hand, being represented by a more general law?

If it represent the proximate cause then it must stand alone; if it do not, then certain influences arising in the nervous system must again be the cause of *it*. Anæmia of the brain is certainly the best condition under which that organ must be placed before sleep be obtained, but is it the cause or only a reflection of the cause? I feel inclined to doubt its being the ultimate cause since certain influences of the nervous system are required to bring it about; consequently, I am inclined to say, it is only one of the links near the end of the chain, but *not* the end link.

VIII.—I will next consider Pflüger's theory, which, to some degree, reverts to the carbonic acid gas theory.

In the *Lancet* of 19th June, 1876, p. 866, we get a good *resume* of his theory, as follows:—

"The functional activity of any organ, he maintains, is caused by the disintegration of living material, which consists essentially of modified albumen; and the excitability of all organs, but especially of the nervous system, is dependent on the presence of intra-molecular oxygen. When this is used up, and has been replaced by carbonic acid, all activity ceases. The intra-molecular conditions accompanying the formation of carbonic acid gas are such that the atoms of its molecules at the moment of its production are in a state of the most violent oscillation, just as in an explosion; and these intra-molecular explosions, which are continually taking place throughout life, excite vibrations in all the atoms around. He compares this process with that which takes place in singing flames; and referring to the grey substance of the brain, remarks that, in the waking condition, the vibrations are the most powerful, the singing of the flame the loudest. Experiments made with frogs long deprived of oxygen have shown that as soon as the formation of carbonic acid gas is arrested, in consequence of the consumption of all the molecular oxygen, apparent death is established, preceded by a period of drowsiness.

"Pflüger therefore holds that the presence of a certain quantity of intra-molecular oxygen is absolutely necessary for the maintenance of the waking state, since this determines the number of explosions; and he regards the conditions of apparent death and sleep as parallel to each other. . . . No other organ" (than the brain) "requires so free a supply of oxygen, its activity being much sooner lost with deprivation of oxygen than the spinal cord or medulla oblongata; whilst disintegrating processes will take place in it, indicated by the formation of acid, even at a temperature of 32° F. But the nervous system, with the associated muscular and glandular organs of the body, form a continuous network of living molecules variously combined with one another by the play of chemical affinities, and of which some are in the act of disassociation, explosions taking place in any part radiate along the lines of the network in all directions, and promote such disassociation, causing, of course, a certain consumption of force. This is especially the case with the grey substance of the brain, the energetic vibrations of which radiate out far and wide during the waking state, and thus augment the consumption of chemical potential energy in all parts of the nervous system and its annexes.

The molecular changes in the grey substance are, however, attended by a consumption of oxygen which is greater than the living molecules can take up in the same time, and the amount of carbonic acid must necessarily diminish. The explosions become less numerous, and a condition that more or less approximates to apparent death is established. The brain no longer maintained in activity by the forces set free in the formation of carbonic acid, if external excitations be withdrawn, sleeps; and, in conformity with this, the work in all parts of the system diminishes."

It has already been noted, in criticising the carbonic acid gas theory, that the long duration of sleep is against it (since the brain might be thought to have ample time for recruiting its supply of oxygen); but Pflüger contends that "the intra-molecular vibrations of the cerebral substance, like the strings of a harp, continue to vibrate long after the blow which has set them in motion," so accounting for the long time required in resuscitating itself.

Pflüger seems to base his theory considerably on hypothesis, and practically, from his experiments in depriving frogs of oxygen and noting the results. Now, to deprive any animal of oxygen is to do away with the element which has to do with the purification of the blood; the result of the deprivation will then be, first, that the animal inhales the atmosphere which it has just been trying to get rid of; and, second, in consequence of this, the expiration of carbonic acid gas is retarded, causing thereby its accumulation in the blood; the effect of which, again, is to produce a condition of asphyxia resembling apparent death, passing through the stage of drowsiness to arrive at that state.

That condition would become aggravated and real death be the result.

Playfair, in the *Northern Journal of Medicine*, No. 1, 184[illegible] thinks that sleep is due to a diminished supply of oxygen; and Dr. Snow, in the *British Medical Journal* for Oct. 2nd, 1873, also states his belief in the same theory.

I can see the force of the theory if looked at in this light—the tired brain cannot take up the amount of oxygen which it does when full of energy, consequently it is provided that the supply of blood, and necessarily oxygen, should be diminished, in order that the latter should be gradually used up till the nerve-cells shall have recruited themselves; but I cannot pin my belief to the fact that, from the experiments on frogs, as before noted, the condition of apparent death so produced and the condition of sleep are identical.

The theories with which I have now dealt clear the way for the consideration of the theory which I myself suggest, and which embraces in it several of the foregoing, in so far as it accounts for the lessened rate of circulation (Atkinson), the anæmia of the brain (as proposed by Blumenbach and supported by others), and the chemical condition lying at the root of the process (Pflüger).

I am of opinion that sleep arises from the working of a natural law,

IX. "Rhythmic Nutrition," and therefore will I term it the Rhythmic Nutritive theory.

Hammond, in his little book on Wakefulness, inclines to think that the cause of sleep is connected in some way with nutrition, and that way I will attempt to clear up.

The law of "rhythmic nutrition" was, if I mistake not, first pointed out by Sir James Paget, and is found to obtain in the case of every or any organ in the body.

It accounts for the rhythm of labour pains, the systole and diastole and period of rest of the heart, the alternation in use of the legs when walking, and the pauses in the respiratory process. It will also hold good in the case of the brain, which differs so much in its functions from other organs.

From the moment of waking till "the brain begins to swim, and the eyes are heavy and dim," it is constantly at work, resting never; it is being exercised when the other organs of the body are resting, and its action being so prolonged there is a corresponding length of time required for its recruiting.

Let us see how some of the other theories fit into this one.

It may seem to some superfluous that I should propose the foregoing theory, since it has such a broad basis and indicates only the starting-point of sleep, but I think the other theories—lessening in the rate of blood-flow, anæmia of the brain, and Pflüger's theory—are only expressions of the conditions which are found to exist during sleep, and are the best means adapting to the end of a proper nutrition of exhausted brain tissue. Lessening of the rate of the flow of blood is of necessity found in the state of sleep, because the conditions which surround its induction—positional and functional—could only bring about this result, and no other. The horizontal position and the absence of muscular effort are the positional elements; while absence of mental excitants, and the needed less supply of blood by the resting organs, are the functional elements. Anæmia of the brain arises as a result partly of the lessened rate of circulation, the less need of the same supply of blood co-existent with the waking state, and partly from the reduced tone of the organ to accept more than a very slight amount of nourishment during the continuous period of sleep.

Pflüger's theory, so far as I accept it, gives an account of the chemical processes lying at the root of the matter, and is so far coincident with the two previous theories.

These three so-called causes of sleep, then, are only the conditions under which the brain must be placed in order to completely bring about its nutrition.

But let me go into this suggestion of mine a little more fully and show what takes place.

The brain may be considered in two aspects—I. Simply as an organ of the body, which, by reason of function, fatigues, and which requires recuperation; and II. As an organ having special and peculiar functions, which requires a special and peculiar mode of repair.

I.—As a simple organ of the body.

The processes of waste and repair are the same, on general lines, as obtain in any other organ—so much waste, so much repair. Most other organs of the body, during the waking condition, have periods of activity, engendering waste, and periods of rest, inciting and encouraging repair. The heart has its period of activity during its systole and diastole, and its periods of rest in the intervals between the beats; the uterus, its period of activity during the régime of the pain, its period of rest between the pains; the lungs, activity in inspiration and expiration, and rest between the respirations. So that in these cases the organs during wakefulness have their periods of activity and rest, their periods of waste and repair. The heart and the lungs never cease to act in life, unless in syncope, but their periods of waste are equalized by their periods of repair, and that continuously; while in the case of the brain things are ordered differently, and that leads me to consider the brain,

II.—As an organ having special and peculiar functions, which require a special and peculiar mode of repair.

From the time that the mind or Ego perceives things outside of itself—be they ideas, emotions, or sensations—till it again looses itself from them, there is a constant exercise of its structure.

Ideation causes waste by there being brought about in its production chemical processes in the brain structure. Emotions, sensations, impressions, and voluntary acts all do the same thing. The exercise of the *six* senses also means that so much mental energy has been parted with, and consequently so much waste. And when we note that one or other or more than one of these conditions are constantly occupying the brain from the moment of resuscitated energy—the waking point—till the point of lost energy—the necessity for nutrition stage—has been reached, we cannot wonder that the stage of repair is brought about in the way it is, that being a condition in which the brain as an organ is entirely at rest, and, consequently, in the best possible state for repair going on.

Let us now suppose the necessity-for-nutrition stage has been reached in the rhythm.

Impressions lose their acuteness; ideas are less boldly grasped; emotions are less easily kindled; and the nervous mechanism, bringing about muscular action, much weakened. Then, according to the position of the body assumed and the state of the organ itself, does there follow a condition of the blood-vessels of the brain, the result of which is that of comparative bloodlessness—anæmia. Thought and mental action entail a considerable vascularity of the brain in their production, and were this condition present in the jaded brain, it would only serve to beat up its reserve energy and cause imperfect rest from functional activity, as obtains in dreams. Carpenter has it that besides the brain continually doing something of which we are cognizant, it is also doing something which he terms "unconscious cerebration," of which fact we are only conscious by results of processes of thought, which lie in our minds, as it were, ready made; this, we perceive, will also add to the sum of exhaustion. Some have said—see the *Lancet* of March 20, 1875, p. 413, in a leading article on dreams—that "the intellect is . . . . in a state of constant activity" during sleep, a doctrine which the Cartesian school also believe; but that, it seems to me, is only the case when dreaming is present. The condition of dreaming means that the brain is stimulated to action, not, however, under the control of the will, and implies that that organ is not being nourished properly. And this is evidenced by the fact that a night's constant dreaming produces mental *ennui*, and often considerable inaptitude for severe mental action on the day succeeding.

Thus it is that anæmia of the brain is the best possible condition of the local circulation for the obtaining of sleep, since a supply of blood beyond a certain amount, which, however, we cannot define, produces mental action of which we are cognizant, but which is necessarily erratic on account of the absence of the will to shape the line of thought. In a word, abstinence of function means, in the case of the brain, a supply of blood which will best suit the nutritive process, but fall short of producing mental action. A slight increase of supply of blood beyond this causes dreaming or erratic mental action during sleep, while voluntary thought and action, as represented in the waking condition, implies the fullest amount of arterial blood that can be supplied.

Now, let us look a little further into the term rhythmic, as applied to the brain. Let us take twenty-four hours and call it a cycle, and we find that during that period the whole of the animal world, for a certain portion of it, are engaged in toilsome, waste-engendering work, and that for the rest of the cycle, enjoy sleep.

The time for sleep, in the cycle, varies. In the lower animal world generally, the time for sleep obtains at the entrance of darkness and continues till the sunrise; in the higher animal world, particularly in the intellectual animal—man—by reason of civilization, the time in the rhythm varies by habit, but that it does arrive, no one, I fancy, will gainsay. The rhythm, then, of the nutrition of the brain may not be so sharply defined as in the case of an organ having a well-marked rhythmic action—as the heart or lungs—but the fact nevertheless is true, that there is a brain rhythm, and that is activity and non-activity, the former meaning a maximum of the waste over the repair, the latter a maximum of the repair over the waste.

Some have said that there is a *periodic* contraction of the blood-vessels of the brain arising from some action in the sympathetic nervous system; that certainly is the fact, but the periodicity is one ill-defined—that is to say, we cannot count upon its appearing at a particular time, owing to various contradictory circumstances.

Moore, in his little book "On going to Sleep," remarks that the sympathetic nerve-supply to the blood vessels supplying the brain is very plentiful. "Around the carotids," says he, "is a large number of them proceeding from the great ganglion in the neck. The vertebrals receive their endowment in less abundance, and chiefly from the second and third cervical ganglia."

Again, Dr. Clouston, in a discussion of a case of Dr. Gairdner's in a case of protracted sleep, gave it as his opinion that there was in the brain a sleeping centre as there similarly is a respiratory centre, which had for its action the induction of sleep; but I would modify this and say that nervous action is at the bottom of the matter, in the way Kirke, whom I have already quoted on this point, says it does, viz., that modifications in nutrition of any organ originate in the sympathetic system from a call on the part of the organ itself, passes to ganglia, and reflected from thence to the vaso-motors, so bringing about altered local conditions of circulation.

To sum up. Anæmia or comparative bloodlessness is the condition present in the brain in the sleeping condition; that condition is the only one during which healthy sleep can be procured, since it permits of the proper nutrition of the brain substance, and falls short of the amount required for mental effort; that in a cycle of twenty-four hours there is a rhythm of activity and sleep, and that that obtains in all brain-possessing animals; that the object of the period of sleep is for the due nutrition of the brain substance, and is a protracted one, because the period of mental activity is also a protracted one, and that sleep is not due to any one particular agency such as anæmia of the brain, insufficient supply of oxygen, or lessened rate of circulation, but is due to a combination of all three in order that the proper nutrition of the brain be brought about; and, lastly, that sleep is due to a rhythmic nutritive process.

XX.—*On the Conveyance of the Contagium of Anthrax to Hair Factory Workers, as illustrative of the Particulate theory of the Contagia.* By Dr. J. B. RUSSELL, Medical Officer of Health, Glasgow, and President of the Sanitary and Social Economy Section.

[Read before the Society, April 28th, 1880.]

THE conception of the infecting elements of communicable disease, as in their physical nature "particulate," commends itself to those whose business it is to investigate outbreaks of such disease by its practical fruitfulness.* Once grasp clearly this conception and you find yourself in possession of a clew which leads with facility and directness to a satisfactory issue through facts which, approached in any other way, seem confused and bewildering. It need scarcely be added that facility in the prevention and repression of communicable disease advances in parallel lines with facility in the discovery of its causes. The object of all such inquiries is, for those strictly practical ends, to discover the original diseased unit in which the series of diseased units, which necessitate the inquiry, began. The particulate theory *dis*-sociates this diseased unit in space or locality and time from the particles or contagia which we desire to *as*-sociate by a sufficient nexus with the series of diseased units whose origin we are required to demonstrate. On the one hand we have the organism which produced, on the other the organism which received the contagium. We find the contagium actively developing, and, in developing, producing disease here and now. We find that the contagium had been actively developing, and, in developing, had produced disease there and then. The problem before us is to connect the two phenomena—the *here* with the *there*, the *now* with the *then*. What I assert is this—that the particulate theory liberates us from the difficulty, in whatever degree it may exist, of dissociation in locality and time, by enabling us to recognize the efficiency and sufficiency of neutral agents which are the media of communication between the organism which produced and that which received the contagium. We have to satisfy ourselves carefully of only two facts concerning those media—(1) That they actually are media, or rather are in a position which makes it possible they may have so acted—*i.e.*, that they at the one end touch or touched the producer, and at the other the produced. They may be continuous between the two, as, for example, a flowing medium like water, or they may be interrupted and isolated from both, as in the case of a solid which floats in air or water, and, raft-like, bears along the contagium, or an instrument such as the surgeon's lancet in vaccination or the unbrushed nails of a slovenly midwife. (2) The other fact of which we must be well assured concerns the essential nature of the medium relative to the essential nature of the contagium. This contagium possesses dormant vital activity. The medium must be consistent in its essential properties relative to the vital conditions of the contagium with the continuance of this potential vitality. In short, it must not partake at all of the nature of, or at any rate must not under the precise circumstances of the case have been able to act as a *disinfectant*. With the physical or physiological properties of the *medium*, which are not related to the vitality of the contagium which it conveys, we must not allow ourselves to be concerned in determining the mere possibility of this medium actually being the *tertium quid* which is to solve our difficulties. We must, therefore, dismiss from our minds all popular preconceptions as to the essential convenience, or even the positive advantages and necessary and habitual usage, of this medium. We must not be puzzled or surprised into doubt by its strangeness, or allow awakening suspicion to be allayed and our attention diverted from a possible medium by its novelty and entire improbability according to all former experience. This is all the more necessary to be remembered because of the order in which in practice the facts usually present themselves. First, you have the series of infected units, then in the course of the notation of surrounding facts which seem to embrace or touch all the units, you come by induction upon a suggestion of the medium, and, last of all, through it to the infecting unit or source whence the contagium was derived and conveyed by this medium. Therefore, any want of firmness and precision in the conception the investigator has of the entire independence of the entity which he is tracking down, of the nature and constitution of the medium by which it may have been conveyed, will inevitably blind his eyes to the leading of his facts. In reference to the proper constitution of the medium, the contagium must be regarded as a foreign body—a pathological adulteration, a casual constituent. This being so of the two qualifications which I have said a medium must possess—viz., the opportunity of receiving the contagium and the possession of properties in harmony with its continued vitality—in practice only the absence of the latter can be regarded as absolutely excluding the medium from the category of suspicion in the presence of strong inductive evidence in favour of its reception. The more experience we have of the opportunities of the infection of a medium which is susceptible to and compatible with the special contagium under investigation, the less we shall be disposed to dogmatize *a priori* as to the fact being impossible of occurrence, simply because we fail for the time to detect the effectual existence of the opportunity.

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* *Contagium* means the physical substance (*substantia*) in which the property of imparting disease inheres. *Particulate contagium* expresses the theory that this physical substance (*substantia*) is not gaseous or fluid but solid. Dr. Farr uses the word "Zymad" for "Zymotic particles," but particulate contagium implies no theory as to the nature of the particles (bioplasm, fungi, spores or germs, &c.) The adjective was first used by Dr. Sanderson, in his paper "On the intimate pathology of Contagion" (12th Report of the Medical Officer of the Privy Council, 1869). In a footnote to p. 237, he says—"Of the three adjectives which might be employed to express the idea that contagium consists of particles, viz., molecular, corpuscular, and particulate, the two former, although more familiar, are objectionable, because the words from which they are derived have been already appropriated. 'Molecule' is understood in physics to mean a hypothetical body of indefinite minuteness, while 'corpuscule' is used in anatomy to denote bodies of much larger size than those in question."

I have thus endeavoured to give the very broadest expression to the first principles of ætiological investigation, such principles as will apply to the contagium of a disease of which we know absolutely nothing; but, in practice, we seldom encounter such a disease. As a rule, we enter upon the inquiry aided by a certain amount of special knowledge of the nature and habits of the contagium, of its ordinary paths of entrance into and exit from the organism in which it produces disease, of the physical properties of the normal excretions of which it is a temporary and abnormal ingredient, of the conditions necessary to the maintenance of its potential activity in any medium, and of the media which are, therefore, preferentially appropriate to this vitality, or absolutely inconsistent with it. Applying these varied details of knowledge specially applicable to the case in hand, we may narrow the field of our induction, and proceed boldly in one direction when we have to deal with one disease, in the opposite direction when we have to deal with another, just as the sportsman knows where he will put up a woodcock or a snipe, and where he will find a hare.

Those of you who are familiar with the history of ætiologic science will recognize how widely the principles of moder differ from those of the ancient or Hippocratic ætiolog Hippocrates deals with "constitutions," that is to say, wit ærial, terrestrial, and other cosmical conditions and phen mena. But I wish to impress upon you that the moder methods by no means exclude those cosmical conditions, fa less attempt to deny their influence. We only say that the are beyond the sphere of practical ætiology. They necessaril condition the evolution of the phenomena of particulate contagia they are concerned in seasonal variations in the prevalence of disease; in regional limitations of disease; in the circumstances which at one time and in one place give wings, so to speak, to the contagia, and at other places and at other times obstruct their progress. We *must* recognize these facts if we wish to avoid the risk of falling into erroneous assertions of success for preventive measures, and also to justify at times what might seem undue confidence or undue anxiety as to the probable course of some disease whose contagium is dominated in its activities by those cosmical conditions. Yet cosmical agencies have only the same relation to practical ætiology as to all biological phenomena, and no other. The canopy of the heavens covers and conditions all the activities of the earth, and the earth bears and conditions all these activities. The sun-spots have most intimate relations to political economy, but I fail to see that political economy could be much advanced by confining our attention to the sun-spots, or looking to them for the solution of the social problems, say of native Indian life. We may as well rehabilitate astrology as attempt to introduce celestial or mundane influences into the guidance of our practice in the control of communicable disease. The farmer observes that in some years he has to encounter exuberant growths of weeds and a progeny of grubs, with which in other years he is not annoyed; but I question if he would find it profitable to study the conjunction of the planets rather than pluck up his weeds and exterminate his grubs as best he may with the appropriate germicides. In like manner, the ætiologist observes that the seasons bring their special tendencies to disease, that temperature and rainfall and hydrometric and electric phenomena are attended by proclivities to some diseases, while they are hostile to others; but, knowing all this full well, he also knows that none of those physical agents can create contagia—they can only condition their existence. Accordingly, he deals with the contagia, and diverts his mind in the midst of his more practical studies with the mysteries and marvels of those transcendental phenomena.

If you scrutinize the objections which are urged against the conclusions arrived at in any particular case of an investigation into the origin of an outbreak of communicable disease, prosecuted in accordance with the methods dictated by the doctrine of a particulate contagium, you will discover that they are based upon the want of a clear conception, in the mind of the objector, of the dissociation of the contagium both from its nidus and its medium. In short, it must be said that the critic does not understand the doctrine which he criticises. Allow me a short proof of this allegation. The great central fallacy into which critics fall is this—regarding the medium as the cause of the disease. In popular language it is convenient and excusable to speak of a medium as a cause, but when we find an attempt made to base an argument upon this popular usage, as if it were a scientific fact, it is time to abandon the usage, or to point out that while it may be convenient it is inaccurate. We may have twenty different and distinct media for the conveyance of one contagium or poison, and popularly we may say that any one of those media poisons, or is a poison, but as a scientific fact there is only one poison and that is the contagium. As an illustration, let me take the contagion of enteric or typhoid fever, which is the most versatile of all the communicable diseases of this country in its choice of a medium. For convenience we may say, in reference to an outbreak of enteric fever, that the victims were poisoned by milk, or by water, or by sewer-gas, but as a scientific fact they were no more poisoned by any one of those media than the suicide is poisoned by the bottle which contained the laudanum which he swallowed, or the tumbler which conveyed it to his lips. This initial fallacy of speaking of a medium as a cause gives birth to a brood of minor fallacies which fall at once before a clear perception of their parentage. For example:—(1) arguments are based upon the erroneous apprehension that one medium is the only medium, or, in the phraseology of the critic, that one cause is the only cause. The inapplicability of one so-called cause to the circumstances of another so-called cause is triumphantly paraded; the fact being that media alone are meant, and the one cause acting through all the media is the contagium. (2) Again, the critic points to the fact that your cause is often present when your effect is absent, or *vice versa*, the truth being that in that case we have not got to do with the relation of cause and effect at all. The medium is not a medium when the contagium is absent. You must look elsewhere for your medium, or prove the intermittency of its action as a medium. (3) Yet again, the natural and essential properties of the cause are adduced in evidence of the absurdity of attributing to it baneful effects; the fact being that the contagium is a foreign and casual ingredient in the medium. The milk is "bland and nutritious," the water is sparkling and palatable; the former, adapting the words of Mr. Lowe, is "the delight of youth and the solace of age," the latter has quenched the thirst of generations of men—how can you say that either is the cause of enteric fever? We answer that we made no such allegation. The contagium is the cause; the milk or water only the occasional medium.

Having thus endeavoured to give you a clear idea of the first principles of ætiological inquiry, I now proceed to give an illustration of the application of those principles in the form of an investigation of the circumstances of a remarkable outbreak of anthrax among hair factory workers.

As the circumstances under which the investigation was conducted were very disadvantageous to the acquisition of an accurate and complete knowledge of the facts, it is necessary to narrate the facts historically as they were ascertained. On 7th March, 1878, rumours reached my ears of a mysterious outbreak of sudden and fatal disease among the workers in a large hair factory in this city. An investigation was immediately set agoing, and these facts collected:—(1) On 26th February, A. M. L., aged 16, hair-spinner, was taken ill, and died on 1st March. She was not seen by any medical man. Her death was registered as from an "unknown" cause, and her body was interred on the 5th March. (2) On 4th March, M. M'C., aged 32, "yard-woman," was taken ill, and died on 6th March. She was not seen by any medical man. Her death was registered "sudden—supposed heart-disease," and her body was interred on the 7th March. (3) On 4th March, A. N., aged 26, "yard-woman," was taken ill, and died on the 6th. She was seen by a medical man about fifteen minutes before death. I saw the body on the 7th, the day after death, and, by reporting the case to the Sheriff's Fiscal, obtained a warrant for a *post-mortem* examination, which was made on the 8th by Dr. Moore and myself. The body was already so far gone in decomposition that the pathological appearances were entirely masked or destroyed, and we could only report that, in our opinion, the cause of death was blood-poisoning, but of what precise source and nature we could not decide.

Contemporaneously with these three fatal cases of illness, there were four girls attacked with symptoms apparently the same in kind, although much milder in degree, and all speedily recovering. Of these, three sickened on 1st March, and one on the 9th. All were employed in this hair factory as "hair-spinning machinists." A fifth girl, S. F., aged 20, a "hair-carding machinist," also sickened on the 1st, but the nature of her illness differed from that of all the others, and gave the first suggestion of the probable source of the disease in them. In the three fatal cases and the four which ended in recovery, the disease was internal and constitutional. It affected the whole organism; but in S. F. it was external and local, or, at any rate, accompanied by a local lesion. On the outer side of the left upper arm there was a tumour, around which the tissues were swollen, and the skin tense and red, while in its centre there was a black, gangrenous spot as large as a threepenny piece. There was a slight degree of constitutional disturbance, but this passed off, the tumour disappeared, and the girl recovered. Although, in the light of this case, and from a careful collation and consideration of the joint symptoms and circumstances of the whole group of cases, gathered from the lips of relations and from inspection of the factory, a definite opinion as to the probable explanation of the outbreak was gradually being formed, in the interval, I shall pass on to the 1st April, when another death occurred, the last of the series. This case also was remarkable in that the woman was not employed in the hair department, and also that her symptoms began with an external lesion, though they rapidly became constitutional. M. D., aged 20, a "fur-cutter" in the factory, sickened on 29th March. Next day she observed a swelling of the left cheek. On the 31st, this swelling had extended over the neck and back. She consulted a medical man, who kindly furnished me with full notes of the illness. He observed "a swelling about the size of a crown-piece on the left side of the forehead." He ascertained that this had preceded the general symptoms, and that from this the larger and more extended swelling had spread. This girl died on 1st April. I again applied to the Sheriff for a warrant to make a *post-mortem* examination, which was carried out on the day after death by Dr. Moore and myself, with the assistance of Dr. Foulis.

This is not the place, nor would it be agreeable to you, to describe in detail either the symptoms which were presented by those unfortunate girls during life, or the pathological conditions discovered in the bodies examined after death. These details will be found in a report published in the Supplement to the Eighth Annual Report of the Local Government Board of England, appended to Dr. Ballard's elaborate inquiry into "Effluvium Nuisances." It will suffice for my present purpose—which is to use this outbreak of disease, and the wide conditions under which it originated, as an example of circumstances which present an instructive analogy to and illustration of the circumstances which promote commoner and more familiar forms of communicable disease—if I rapidly run over the path by which I reached my opinion as to the nature of the disease in question.

I have stated that the case of S. F. gave the first hint towards a solution of the mystery. The tumour upon her arm was undoubtedly a malignant pustule caused by infection with the animal poison, which conveys the disease known as Anthrax, Charbon, Milzbrand, Splenic Fever, Malignant Pustule, &c., &c., which is primarily an affection of horses, horned-cattle, and sheep, but which may be communicated to all warm-blooded animals, including man. In the blood and fluids of the body of the girl, M. D., which was the only one which we had the opportunity of examining satisfactorily, we actually discovered the contagium of this disease—viz., the *Bacillus Anthracis*, a fungoid organism which infects the blood and tissues, which in its full development assumes a rod-like form and is very perishable, but which propagates by spores which are very tenacious of life, and, in fact, are, when dried, practically imperishable. The detection of this easily-recognized organism is absolutely decisive of the disease. In the other cases we had, in the circumstances, no opportunity to discover it; but we can fall back upon the general symptoms, as ascertained in the only way possible in the absence of medical attendance, from the lips of friends and relatives who witnessed the course of the illness. Having noted those symptoms and compared them with the symptoms in the case of the group in which the Bacillus Anthracis was found, and with the account of similar cases put on record from time to time by foreign authors, we obtain conclusive proof of the identity of the disease in the entire group.

The variety in the nature of the disease in these cases has an interesting and important bearing upon their causation, and may, therefore, be more particularly discussed.

Anthrax assumes different aspects, apparently depending on the mode of access of the contagium to the system, *i.e.*, according as it is inhaled or swallowed, or enters locally by the hair-follicles, or other natural or artificial openings in the skin. In the former case it is called Charbon fever (*Fievre Charbonneuse*), Intestinal or Internal Anthrax, and *Mycosis Intestinalis*, the symptoms being from the outset constitutional. To this category the cases of A. M. L., M. M'C., and A. N. belong. In the latter case it is known as Malignant Pustule, Charbon, or Anthrax proper, the constitutional symptoms being preceded by, or at any rate advancing *pari passu* with, certain characteristic local appearances of the nature of a carbuncle or pustule. To this class belongs the case of S. F. The last fatal case, that of M. D., also belongs to this class, but to the most rapidly fatal form of local infection, or it may be to a combined local and constitutional infection, in which the contagium at once passes from its local nidus into the surrounding tissues, and thence permeates the whole body. This has been styled Œdematous Charbon (*C. œdemateuse*), Malignant Œdema (*Œdeme Malin*), or Malignant Anthrax Œdema (*Bösartige Anthrax Œdem*).

The general circumstances under which Anthrax manifests itself in man are these. It is always observed in persons employed either in the care of animals during life, in their slaughter, or in trades and manufactures connected with the utilization of the various parts of animals. The localities in which outbreaks have been observed in man are, therefore, either Anthrax districts—*i.e.*, districts where Anthrax is prevalent among animals, or places at a distance where it is unknown as an epizootic, but to which, in the course of commerce, the products of infected animals have been conveyed. As every single item of these products may be a medium of infection, the ultimate place of manifestation of the disease is as varied and widely distributed from the original focus as the products and their destination. Hair, wool, bristles, hides, horns, hoofs, &c., being valuable articles of commerce and in wide request, those parts of animals have furnished the most startling demonstrations of the vitality and portability of the disease by its propagation to man. Hirt (24) thus enumerates the various classes of workpeople who have suffered:—"tanners, makers of coarse hats, fell-mongers, furriers, fur-dyers, workers in horse-hair, wool and paper factories, and rope makers, who clean hair brought from abroad—*e.g.*, from Russia" (p. 102). This reference to the special likelihood of Russian hair conveying the infection, shows that anthrax may so constantly be present in certain countries as to mark out the spoils of their animals as specially likely to contain and convey the disease. We are told by several writers that there is no country where anthrax is more constantly present and severe in its ravages among horses and horned animals than in Russia, more especially in Siberia. In Siberia horses are the chief victims.

We have, therefore, arrived at this stage of our inquiry into this outbreak of disease—that the disease was anthrax in its several recognized forms; that those persons were all employed in the manufacture of hair; that hair is a well-known medium for the conveyance of the anthrax contagium, and that Russian or Siberian horse-hair is especially likely to act as such a medium, because anthrax in that country is a chronic epizootic. On inquiry at the Factory I learned that the hair which was in hands at the time of this outbreak was that known in the trade as "raw Russian manes,"—*i.e.*, the mane hair of Russian horses collected and exported without cleaning. It is obviously necessary to inform ourselves of the nature of the trade processes to which this hair was subjected to ascertain in what department of these processes the affected persons were engaged, and how their illnesses stood related to the period within which this hair was operated upon, because Russian hair is not the staple of the hair manufacture. It is only used for certain purposes, and therefore only occasionally.

The nature of the trade processes is most important, because in any case an infected medium only imparts its contagium under certain conditions. In this case the condition is such mechanical disturbance as would dislodge the contagium and spread it as dust in the air. If left alone, a medium impregnated with dry contagium is innocent enough. It possesses no power of active aggression. This hair factory is very extensive, the premises are so commodious that each department is sufficiently accommodated, and the apartments are all large and airy. It is not my intention to describe all the processes applied in all departments of this interesting trade, but merely those to which this hair was subjected. The "raw Russian manes" are received in bales, and on this occasion these were first disturbed in order to be put through the process of "willowing," or violent rotation in a machine whose internal mechanism consists of four cylinders studded with iron spikes, which revolve rapidly so as to tear up the hair and free it from dirt, the coarser parts of which fall through the open meshes of a wire bottom into a box, while the finer dust passes up, to be expelled by fanners through a shaft into the open air. The hair is introduced and removed in lots as cleaned by the front aperture. It next passes to the "carding-machine," which removes the finer dust by similar violent rotation, and gives a gloss and elasticity to the hair. These machines are ranged in a long shed open to the roof, and are constantly surrounded by an atmosphere of dust. Their whole work is effected by rapid movement of a parched, unadhesive material, charged with dried *débris*, mostly of animal origin, which it expels as dust. It is not, therefore, in the nature of things, possible that the work of feeding and tending these machines can be prosecuted without filling the lungs and powdering the exposed skin and garments of the workers with this dust. The hair is now ready for the spinning and curling machines. For this purpose it is conveyed up a broad stair from the middle of the machine-shed to the second flat of a building which runs parallel to it. This flat is spacious, lofty, well-aired, and lighted by numerous windows on each side. The operation of spinning closely resembles that of ordinary rope-making. The girls carry the horse hair in bags tied round their waists, retreating backwards, applying successive portions of hair therefrom to the revolving rope, so that any remanent dust or microscopic particles may be thrown up just about the breathing level. The tightly-twisted and coiled ropes are now carried down the stair through the machine-shed to large steam-chests in the yard, where they are boiled and steamed for 20 to 30 minutes, afterwards to be stove-dried. The object of this process is "to set the curl," which is necessary to produce the elasticity of the hair when used for mattresses, &c. It is scarcely necessary to remark that this boiling also disinfects, and the subsequent manipulation is unattended by risk.

Hoping that this short description will suffice to give you a clear idea of the physical circumstances relative to the hair and the hair dust in which the persons employed in those various departments found themselves, let us now collect the facts as to those who were infected with anthrax. The "Russian manes" were put in hands on 16th February and withdrawn upon 2nd March, when the proprietors heard of the death of M. L. There were 9 cases of illness in all, 4 ending in death. As to date of attack 5 sickened *within the Russian manes period*, 2 in two days thereafter, 1 in six days, and 1 in twenty-seven days. Classified as to their departments, 5 were engaged in hair-spinning, and 1 went into the hair-spinning flat to remove the ropes—all passing to and from the flat through the dusty atmosphere of the machine-room; 2 were engaged tending the machines in this machine-room, and 1 was employed in a distinct department of the business—viz., the fur-cutting, but opposite a window which faced a door in the machine-shed, and was provided with a ventilating pane of glass. We have seen that two forms of anthrax are recognized, the internal arising from poisoning by inhalation, and the external arising from the deposition of the contagium upon the surface of the skin. There were 7 cases of internal anthrax, of whom 6 were hair-spinners and 1 removed the ropes from the spinning-flat; and 2 cases of external anthrax, of whom 1 was a carding machine-tender, and the other was a fur-cutter.

Now, assuming the "Russian manes" to have been the infecting medium, there are two facts which demand explanation. (1) The sickening of four of those workers, after this hair had been withdrawn from manufacture; (2) the seizure of the girl M. D., not merely 27 days after this withdrawal, but although she was employed in an entirely different department, and was not necessarily in contact with this hair at all. The difficulty involved in the former fact arises from a question of time, in the latter, from one of space and time. The solution is bound up with the determination of the incubation period of the anthrax contagium, and the laws which govern its local diffusion. But these questions may be intimately related—*i.e.*, there may be something in the physical condition and laws of diffusion of the contagium which makes the difficult question of incubation in certain circumstances of comparatively little importance. The incubation period of anthrax is said by Raimbert to be 1 to 3 days, by Bollinger to be sometimes very short, but usually 3 to 4, or at most 5 days; and by Virchow to be most commonly a few days—rarely longer than 11 to 12, but frequently only a few hours. We might therefore bring the date of infection of all those cases save one easily within the "Russian manes" period, since they sickened from 2 to 5 days after its cessation; but the exception—viz., the fur-cutter—goes quite beyond the scope of the incubation interval. She tended a machine for shaving the fur from rabbit skins. Now, both hares and rabbits are known to contract anthrax in districts where it prevails among cattle, apparently from feeding on the same pastures. Further, Raimbert tells us that rabbit-skins have been observed to communicate the contagium to man (14, p. 146). But in the present case any such effect would probably have manifested itself at a previous stage of the manufacture, viz., in the dusty process of combing and cleaning before the skins reach the fur-cutting department. But there was the open window facing the door of the machine-shed, and convenient for the access of the dust-impregnated atmosphere. I believe, therefore, that the rabbit-skins were not the medium of infection, but the hare in this case, as in that of the other girls who were actually in contact with it. The fuller explanation of the grounds of this opinion is involved in the general physical phenomena governing the distribution of the anthrax spores in the dry condition, the consideration of which I shall defer until we have gathered the scattered records of similar occurrences in the experience of hair factories. We shall then have a more extended series of facts to aid us in associating this, at first sight, anomalous case with the others, in one harmonious and consistent explanation.

The fact that anthrax is enzootic in the pastoral districts of all the chief European countries excepting Great Britain, sufficiently accounts for the circumstance that all our precise knowledge of the disease both in the lower animals and in man is derived from the observations and investigations of foreign writers. It is nevertheless remarkable, considering our commercial relations with those countries, and the existence among us of old-established and extensive hair factories, that so far as I can discover, only one casual record has been made of malignant pustule in connection with an English hair factory.

Indeed, in Thackrah's (4) small treatise on Trade diseases, published in 1831, the first work in the English language devoted to the systematic treatment of this department of hygiene, we find this passage, which proves that it was not want of knowledge or observation of the hair-trade in its health aspect which caused the communication of specific infection to be overlooked:—"Preparers or dressers of hair—men, women, and boys—are in an atmosphere of dust and stench, *especially when employed on the foreign article.* The winnower suffers most. The complexion is soon rendered pale, the appetite reduced, the head affected with pain, respiration impeded, cough and expectoration established, the body emaciated; I scarcely need add that life is sacrificed to a continuance of the employ" (p. 69).

Therefore "foreign" hair was then imported into England, but was known only as more productive of "dust and stench" than the home article. That specific infection was not observed even more recently becomes the more remarkable when we remember that Dr. William Budd read a paper before the British Medical Association in London, in 1862, entitled "Observations on the occurrence of malignant pustule in England, illustrated by numerous Fatal Cases" (published in *Brit. Med. Journal* for 1863). At that date he could not refer to a single case in association with a hair factory in this country (evidently not being aware of Mr. Lawrence's cases, which were published in 1847), but he quotes two continental examples. Yet, with these suggestive incidents so widely published, no similar mishap seems to have attracted attention in this country during the intervening sixteen years. Additional facts made out in reference to the Glasgow hair factory, discovered and interpreted in the reflected light of the events above recorded, make it unfortunately too probable that we cannot infer from the absence of any record of such outbreaks of anthrax among British hair-workers that no such outbreaks have occurred. The probability is that they have occurred from time to time, but being chiefly of the internal variety, as in the Glasgow outbreak, have not been recognized.

I shall give you, as shortly as possible, such notices of the hygiene of the hair trade as I have been able to collect in the course of my reading on the subject. Heusinger (8) quotes from the *Memoires de l'Academie de Med.*, so far back as 1777, the following passage—"Malignant carbuncle in Paris, as a rule, only affects those engaged in two trades—the tallow-chandlers, or those who work with mutton fat, and *horse-hair workers*. The latter are most frequently affected; indeed, it is seldom that they pursue this trade long without suffering from it, and many die. They have observed that *the hair whose manufacture is most dangerous is that which is imported from Russia.* This hair is usually in a bad condition; a part is sometimes transformed into grey dust, and has a disagreeable smell. The case of carbuncle which Paulet saw was that of a young woman who had opened a bale of this hair" (p. 403). In 1822, Patissier published a book based upon Ramazzini's historic treatise "*De Morbis Artificium*" (Padua, 1713), a section of which is entitled "*Maladies des Criniers.*" He there states:—"Workmen who unpack bales of hair and who beat them are liable to contract malignant charbon and boils. The '*Gazette de Sante*' (March, 1777) contains the history of some workmen who had been attacked with those diseases, after having opened and sorted *bales of hair imported from Russia*, without sufficient precaution" (1, p. 242). In 1860, Vernois, in his "*Traité pratique d'Hygiène industrielle,*" has an article "*Crins (Preparation des) Appret et teinture,*" from which we learn that this trade was by the French Government, in 1843, placed in the third class of dangerous employments as requiring police supervision. Among the "*causes d'incommodité*" he mentions "dust in the beating and sorting rooms. Sometimes the occurrence of serious mishaps to the workers, through the hair being impregnated with the blood of animals dying of charbon or glanders." In Tardieu's "*Dict d'Hygiène*" there is an article, "*Criniers,*" in which those risks are mentioned as common, and certain precautions are recommended.

Rayer (3) states:—"During the three years that I was attached to the Hospital St. Antoine, I saw several cases which all came from the same manufactory in which the business of *cleansing and preparing hair imported from Russia* was carried on" (p. 558). Budd refers to this statement, and says that these cases were eight in number, and calls them "malignant pustule," but Willis' translation of the second edition (1835), to which alone, and to the original first edition (which contains no mention of the facts), I have had access, specifies no number.* In the translation, one hair factory case is detailed, and three casually mentioned, all of date 1829, on the statement of one of these patients. Two are undoubted illustrations of the true external anthrax, the local tumor being on the face and neck in one, and on the thigh in the second. All were fatal except this last. Rayer says:—"According to the patient, weakness, prostration, and spitting of blood are symptoms of frequent occurrence among the workers in hair. His daughter had died after an illness of five days with symptoms of this description, and one of his fellow-labourers had sunk some time previous in two days" (p. 567). This rapidly fatal case is certainly suggestive of the internal form of the disease. Another fatal case of external facial anthrax is detailed, which occurred in a female "carder of mattresses." Proust (25) also refers to the liability of "mattress makers" to charbon. Budd says:—"I think it is the same writer (Rayer) who records the still more remarkable case of three persons who were attacked with the disease after cleaning some hair that had for many years served as the stuffing of an easy chair." I have not been able to verify that reference to Rayer, but such an occurrence is quite within the range of possibility. Given the contagium *in a dry condition,* and it seems to have no limit to its potential vitality.

There is a valuable special paper on the association of hair manufacture with charbon by Dr. Ibrelisle (5) published in the *Annales d'Hygiène* (1845)—"*Sur les Accidents qui peuvent resulter de la Manipulation des Crins.*" It is introduced by the following remarks on the general question by the editors:—"Experience has superabundantly proved that animal matters long accumulated yield a dust which is extremely injurious to persons who breathe it. This is especially true of *hair*. This material, charged with cutaneous secretions and blood, befouled by fœcal matters which escape at the moment of slaughter or of natural death, is packed in bales to be exported from Brazil, Buenos Ayres, or Russia. It yields a dust from animal *débris*, fermented and changed in character, which will certainly prove poisonous if inhaled in great quantity. It is not necessary, for the explanation of this poisonous property, to assume that the animals have died of contagious diseases" (p. 339). The editors of the *Annales d'Hygiène* doubt the specificity of the effects of foul hair; and certainly Dr. Ibrelisle's cases of malignant anthrax are peculiar in this, that they were distinctly associated with other cases of boils or simple furuncule. They occurred among the male prisoners in the prison of Metz, and *only among those who were employed in beating, picking, and teasing hair*. Dr. Ibrelisle says that the employment was very dusty, and that the foreign hair produced a risk, not only from the dust but from contagious diseases. He bears distinct testimony to the fact that these risks were well known to attend all hair manufacture—"Medical men, who have studied the diseases of artizans, regard work among hair as very dangerous to those who engage in it." One-third of all the prisoners engaged in this work were attacked, an excessive proportion, which he attributes to the small, ill-ventilated cells in which it was carried on.

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* Budd probably refers to an edition published in 1845, which I have not seen.

Trousseau's cases are quoted frequently. He states (*Gaz. Med.*, January, 1847) that in two Parisian factories for working up *horse-hair from Buenos Ayres*, and in which only six or eight hands were employed, twenty persons died in the course of ten years from malignant pustule (7).

In the Second Annual Report of the State Board of Health of Massachusetts, U.S.A., for 1871 (19), there is a paper giving a very complete account of 26 cases which occurred between 1853 and 1870 among the workers in a hair factory in the town of Walpole, in that State. The whole history is so analogous to what we shall subsequently see has been the history of the disease in Glasgow, that I must give it in some detail. The first case occurred in 1853. A workman was taken suddenly ill, and died in two days, a well-marked characteristic vesicle having meanwhile appeared. The next case occurred in April, 1861, when "another man expired after an illness of 24 hours, having obscure symptoms of blood-poisoning, but without the appearance of any vesicle. Two months later this was followed by another case, accompanied by a vesicle upon the neck." *These isolated cases attracted little attention at the time.* "In March, 1866, another operative died, manifesting unmistakable symptoms of charbon, and from that time till July, 1869, the disease seems to have lurked about this same factory, indicating its presence at pretty regular intervals. During this period seven or eight cases have occurred each year, the average number of operatives employed being about eighty." The following table shows the total number of cases up to November, 1870, their nature and results:—

	Cases.	Died.
Malignant vesicle, . .	15	5
Internal lesions, . . .	10	8
Malignant œdema, . .	1	1
Total, .	26	14

In the 15 cases of malignant vesicle, the external lesion was situated in 6 cases on the neck, in 5 on the face, in one each upon the shoulder, nose, scalp, and arm. Of the eight fatal cases of internal anthrax, five succumbed within twenty-four hours of the attack. Of the twenty-six cases, twenty-four were employed in manufacturing curled hair. Of the other two, *one was a carpenter, who, a short time previous to his attack, had worked about the buildings connected with the factory, and the other was seized shortly after having nursed her husband, who had been ill with the same malady.*" As to the source of the hair which introduced the contagium, we are informed that it was "sheared from the necks and tails of living wild horses, and is imported in bales, for the most part from Buenos Ayres, *a small portion only being brought from Europe.*" This latter statement suggests the question, whether the "small portion" was of Russian origin, but no further information is given. The process of manufacture was much the same as that pursued in the Glasgow factory. The report proceeds—"During all these processes, the hands of the operatives are brought constantly in contact with the hair, while in the vicinity of the picking-machine the air is loaded with minute particles of dried animal matter, so that there is every facility for absorbing the poison by both contact and inhalation." It is noted that some specimens of the hair were quite clean, while others were "often matted together with dirt, and putrid animal matter." Repeated inoculation experiments were made upon rabbits with this animal matter, but "without producing any characteristic effects." Virchow made similar experiments upon dogs and guinea-pigs, but with the same unsuccessful result (10, p. 387). This is in precise accordance with the fact that only certain parts of the total bulk of each bale were derived from infected animals. The Bacillus Anthracis was discovered by Drs. Stone and Rodgers in two of the cases—one of external pustule, which, though very severe, ended in recovery; and one of the internal variety, which ended fatally. In Mr. South's additional notes and observations, in his translation of Chelius's System of Surgery (6), published in 1847, I find the only record of cases of malignant pustule arising in an English factory. Three cases were communicated by Mr. Lawrence, of whom two "*were persons employed in a horse-hair manufactory*" (vol. i., p. 69).

In a paper by Wagner (22), "*Die intestinal mycose und ihre Beziehung zum Milzbrand*," there is a history of a series of cases observed in Leipzig, with ample details of symptoms, pathological appearances, and microscopic examinations of the tissues and fluids. We shall confine ourselves to the facts bearing upon their ætiology —(1) A dyer of sable-furs died in hospital two hours after admission, 25th Nov., 1872, his illness lasting about twenty-four hours, ending in epileptic convulsions, opisthotonos, and coma. (2) A hair-rope spinner, aged 23, who had been engaged in the manufacture of *Russian horse-hair*, walked into hospital, 31st March, 1873, complaining of diarrhœa, cramps confined to his left side, and colicky pains, his illness having begun twenty-four hours previously. He died almost immediately. (3) A clerk, aged 30, entered hospital, 26th June, 1873, and died in twelve hours; awoke feeling ill on 21st, but worked until the 24th. He was employed in the goods department of a railway. (4) A message boy, aged 16, employed in a factory where *Russian horse-hair* was in hands, observed a vesicle at left angle of lower jaw on 30th August, and entered the hospital on 1st September, collapsed and cyanotic. He died on the 3rd. These cases furnish the basis of the paper, but the following are collected and added:—(5) A hair-rope spinner, aged 18, employed in the same work as (1), who had been *carding Russian horse-hair* which was intermixed with ox-hair, died a week after observing a vesicle under his chin, 20th February, 1870. (6) This case led to the discovery that "a workman in the same work had two months previously become suddenly ill, and died quite unexpectedly." A homœopathic practitioner regarded the case as pneumonia, "although he thought it obscure, and could not account for the death" (p. 29). (7) A hair-rope spinner, aged 21, died 6th July, 1857, with symptoms of peritonitis, after an obscure illness of about a week. (8) A bristle-binder, aged 60, died 27th March, 1875, after a rapid illness of twenty-four hours, in which headache and vomiting were prominent symptoms. In cases 1, 2, 3, 4, 5, and 8 the Bacillus Anthracis was found in abundance. Cases 6 and 7 are associated by Wagner with the others in the light of their ascertained nature, as being the same disease, but not recognized at the time. He also gives references to similar cases, not, however, in hair-workers, and quotes Neyding, of Moscow, as saying that malignant pustule was observed by him most frequently in workers in hair and bristle factories. Münch also had examined in Moscow, within four years, no fewer than 28 bodies of persons who had died of this disease. In 15 there was external carbuncle, in 2 it was very small and insignificant, and in 11 there was no external lesion whatever. These cases mostly originated in works where horse-hair and similar animal products were manufactured. Wagner adds that in Leipzig such cases never occurred in hair-works where Russian or Siberian horse-hair was not used, and tells us that workpeople employed in the same works which supplied the fatal cases of *internal* anthrax were frequently treated for *external* anthrax in the surgical department of the hospital. He thinks that the bacteria obtain access to the stomach with food, it being customary for the workers to eat some of their meals in the workroom, the viands being powdered with infected dust, or contaminated by the unwashed hands of the workers.

We see, therefore, that in Great Britain, France, Germany, and America, hair from Russia—the country which is well known to be chronically infected with anthrax—has most frequently, in fact almost invariably, been the medium which has conveyed anthrax to workers in hair, while not unnaturally in Russia itself this disease is frequent and deadly among those workers.

These are the facts of instances of anthrax infection through the medium of hair, occurring in the ordinary course of events in the practice of a trade. We may usefully supplement these facts by a short reference to experiments, in which the conditions were created, and were therefore under rigid control. The presence of a specific organism in the bodies of animals dying of anthrax, was first detected in 1850. This organism is so easily recognized and isolated for experimental purposes that from that date until now it has been the subject of study at the hands of a host of accomplished observers. The result is that we have not only obtained a minute acquaintance with the nature and habits of Bacillus Anthracis, but also from this knowledge a flood of side-light upon the phenomena of infection in general. This bacillus is found to exist in two states—the one fully developed as rods, the other as spores. Its vitality in the former state is evanescent, in the latter it is tenacious. In the dry condition there seems practically to be no natural limit to its potential or latent activity. Moisture and the supervention of decomposition seem to be the only physical circumstances which terminate its organized existence and infecting powers. Once let the medium in which the *resting-spores* of this bacillus exist, be dried, while yet fresh—whether that medium be some portion of the animal, as bones, hides, hair, horns, blood, &c., or something which has emanated from or been in relation to the animal, as excrement, hay, straw, rags, &c., which do not contain the contagium in their structure, but include it in their bulk—and those materials become a perennial medium of infection in appropriate circumstances. The three most recent experimental investigations of the contagium of anthrax are those of Lemke, of Göttingen (26); of Toussaint, of Toulouse (27); and of the veteran Pasteur. Lemke's inquiry has most direct interest for us, as it consists of experiments which establish the possibility of infection by the entrance of spores into the blood through the intimate structure of the lungs, when inhaled by the air-passages. He rubbed up portions of dry infected material with starch, so as to produce a fine powder, which could be inhaled by animals through an artificial opening in the windpipe—the wound having been allowed to heal, and being also protected otherwise from the possibility of infection of the cut surfaces. He found that in this way sheep and goats were fatally infected with uniform certainty. The disease produced was, as in the case of the hair-workers, internal anthrax, and the *post-mortem* appearances were precisely those observed in their bodies—even to the rapid occurrence of decomposition and the exudation of bloody fluid from the nose and mouth. Toussaint made quantitative experiments with infected material, and found that the rapidity of the supervention of constitutional symptoms and the gravity of the result corresponded accurately with the estimated quantity of the contagium introduced. By frequent experiments, followed by careful dissection of the bodies of the animals experimented upon, he was able to associate certain *post-mortem* appearances with certain modes of infection. Applying this knowledge to the results of dissections of the bodies of sheep killed by spontaneous anthrax, as distinguished from anthrax thus artificially induced, he proved that the contagium had entered by the mouth and pharynx, or by inhalation. Here again the lesions described as discovered in those animals corresponded accurately with those observed in our hair factory workers. These and other experimenters have also supplied us with the nexus between the functional life of the Bacillus Anthracis and the morbid symptoms in the animal with whose health those functions interfere, and consequently produce disease. They consume the oxygen which is alike necessary for their existence and for the existence of the animal. Flourishing and multiplying by the aid of this oxygen, they come ultimately to produce mechanical obstruction in the capillary blood and lymph vessels. Hence, first, you have cyanosis or lividity, indicating the condition of asphyxia or breathlessness, and then ensue local congestions, œdema or watery effusion into the tissues from the obstructed vessels, and hæmorrhages or outpourings of blood, internal and external, and the various functional symptoms such as convulsions and spasms. In infection by inhalation the spores at once obtain entrance to the most oxygenated part of the body. They are plunged into the fountain both of the animal's life and of their own. Hence the rapidity of their development and the fatality of the constitutional disease which they establish.

We are now in a position to give the history of these outbreaks of anthrax among hair factory workers from the very beginning. In Siberia especially, but in all the pastoral provinces of Russia, anthrax has always been a prevailing epizootic. It is there that the severest outbreaks among horses recorded have occurred, because there horses are reared in herds, as horned cattle and sheep are in other countries. Being deprived of that individual care and observation which the horse enjoys in populous countries, that animal becomes the prey of this disease in enormous numbers, as horned cattle and sheep do wherever they are reared in a like manner. In some years above 100,000 horses are known to have died in this way in Siberia alone. In all countries where internal government is sufficiently established, the utilization of any portion of an infected carcase is forbidden. The body is required to be slashed over the surface to destroy the hide and buried deep in the earth. But everywhere individual cupidity and ignorance defeat those measures of prevention, the observation of which is required for the general good. We are told that Russian hair "is gathered from all available sources by the peasants, and is sold in small parcels to individuals who collect it at fairs, &c. These persons make it up into larger parcels and sell it to merchants. The result of this is that hair, as it reaches the merchant, is the mixed product of innumerable places in the district where it was originally collected" (Ballard, p. 44). In the horse, the manes and tails are the commercial product, so far as hair is concerned. Anthrax in one variety is accompanied by discharges both from the mouth and bowels; in another, there are boils and sores which chiefly affect the throat and the region of the neck and fore quarters. Therefore manes and tails are certain to be soaked and impregnated with infected matter. Some samples are filthy and matted together with animal refuse. When derived from horses infected with anthrax, this animal *dèbris* is mixed with the resting-spores of Bacillus Anthracis. These have dried while the medium which conveyed them from the body was fresh, and have thus been endowed with perpetual potential activity. The parcels bought by the merchants at the fairs are made up in bales for exportation, and wherever they go, from time to time in the course of manufacture, they have, for a hundred years at least, been associated with outbreaks of anthrax among the workers. In the Glasgow case we have bales of "raw Russian manes." They are passed in succession in portions through the processes of willowing, carding, and spinning, the whole object and result of which is violently to disturb, dislodge, and dispel those infected matters in the form of dust. The manes used at this time were not crudely dirty, but certainly dusty. The immediate effect of so treating anthrax hair was to create an infected atmosphere, which not only pervaded the machine-shed and the spinning-flat, but must have at the date of the accident extended outside, as the lighter portion of the *debris* was conveyed by shafts through the roof of the shed and discharged in the open air. A constant stream of dust could be seen pouring out. The vacant ground intervening between the machine-shed and the spinning-flat was powdered with this dust, and seeds of various kinds which had escaped digestion or been entangled in the hair of the animal were germinating here and there. There can be no doubt that the more deadly seeds of anthrax were present in this *debris*, and from their lightness more plentifully suspended in and conveyed over a wider area by the air. We may therefore conceive of the spores as distributed in the atmosphere surrounding those buildings, as settling down in quantity on convenient surfaces in corners here and there, ready to [illegible] [illegible] to be again blown into dust, and so prepared for inhalation, or to be deposited upon the skin of any person who happened to be near. Only amid those physical conditions [illegible] described, and every one of the cases is brought within the scope of their action. All the workers attacked were either actually engaged in the dust-producing processes, or indirectly brought within the sphere of their influence. The case of the fur-cutter is precisely analogous to that of the carpenter in the W[illegible] outbreak. We are told that a short time previous to the attack he had worked about the buildings connected with the factory. Among Wagner's cases also, we find a message-boy [illegible] employed in a hair factory. The month of March, 1870, was unusually warm and dry. There were only 11 days on which rain fell, and then in slight showers, so that the total amount was but [illegible] inches. The fur-cutter sickened on the 25th, and during the preceding 17 days there had been only on two occasions any [illegible] showers. It has been observed that anthrax among animals is most severe in hot and dry summers. Koranyi and Len[illegible], in classifying cases of this disease in man, found that 71 per cent. fell in the three hottest months, viz.—July, August, and September. Heat and drought are therefore the epizootic and epidemic constitution of anthrax. Why the fur-cutter, the carpenter and the message boy, and only a few women, among the many who were exposed to infection, were infected, while the great majority escaped, is a question easily to be solved, in perfect consistence with the general phenomena of all infection on the particulate theory of the contagia. The law of infection is worked out and eventuates in the presence of such controlling circumstances as the physical facts of the case create. The material germs of disease are unequally distributed in the medium which contains and conveys them, and the actual infection follows or not upon the efficient or inefficient dissemination of the individual exposed. In the present case, not all the manes included in the bale were derived from infected horses. At any rate, we require only to assume the presence here and there in the general aggregate of an infected parcel. One portion separated and placed in the machines would be infected, another not: so that, by intermittent spurts, the dust constantly disseminated became and ceased to be dangerous. Therefore, in strict accuracy, although Russian hair has so frequently proved that it embraces infected parcels, as to be marked out in distinction from hair from other countries as dangerous, only particular parcels are infected, and we have after all, even in its manufacture, only to deal with an intermittent source of disease. When we, besides, recall the other factors which enter into the determination of the result—disease or no disease; as, for example, the presence of a person in a precise spot at a precise time, the occurrence of a shower at this precise place at this precise time, and many other instances apparently trifling, but in this relation most momentous, we can at once recognize what a complicated problem in probabilities is before us.

One feature of these cases which is in entire accordance with this scheme of causation, I shall merely mention. The type of disease communicated corresponds with the conditions under which infection occurred. Of the 9 Glasgow cases, 7 were examples of *internal anthrax.* Of the 26 American cases, 10 were internal. Wagner's cases are all internal. In Russian factories the majority are of this type. Internal infection is due to the inhalation of the spores or their ingestion with food. I have told you that experimental inhalation produces the same symptoms and *post-mortem* appearances as are found in man, when the surrounding circumstances are such as to facilitate the impregnation of the air with spores. A case has been recorded in a slaughter-house forage-master, several cases in bristle-binders, and in other trades which have to do with dry and dusty animal products. The only other trade which equals the hair manufacture, in creating necessarily and on a large scale an infected atmosphere, is that of the wool-sorter. In Bradford this trade has for years been attended with fatal illnesses, carrying off those engaged in it from time to time. Much mystery has hitherto attended the explanation of these occurrences, but since my attention has been directed to those accidents, if they can be called such, in the hair trade, I have had no doubt that "wool-sorter's disease" is simply internal anthrax. In wool-sorting, almost as thoroughly as in hair-cleaning, trade processes co-operate with the characteristics of the anthrax contagium to produce the most favourable circumstances possible for internal infection.

When we have discovered a new medium by which in a particular case the contagium of a well known disease has been disseminated, it can rarely if ever happen that we have detected this medium on the very first occasion in which it has acted as such.

[illegible] of the [illegible] diseases [illegible] important [illegible] with reference to the circumstances [illegible] have been mentioned [illegible] believe that [illegible] suggested [illegible] Fortunately, therefore, the whole [illegible]

[illegible] Russian hair had been [illegible] their [illegible] hundred years been [illegible] For the present narra[illegible] this outbreak [illegible] The death of A. M. L. was registered [illegible] M. M'[illegible] as "sudden, [illegible] unknown." Yet now, [illegible] to doubt that all three [illegible] There is therefore reason to suspect that [illegible] time to time have been overlooked. [illegible] or at least a strong probability, [illegible] in this same factory, which [illegible] died on 12th Oct. 1878, in the [illegible] of what was readily recognized by her medical attendant [illegible] malignant pustule situated on the [illegible] form of anthrax. She was a hair-spinner. [illegible] days previously the foreman of the spinning department had died after four days' illness, of what was certified to be "delirium tremens," but with symptoms and under circumstances which point very decidedly, under the reflected light of subsequent events, to internal anthrax. Russian hair was the material in hands at this time. On 1st June, 1877, a hair-carding machinist died on the fourth day of an illness which was registered as "Inflammation of the brain," although no medical man had seen her, and no *post-mortem* enquiry was made, but which there can be no doubt was internal anthrax, probably of the same type as the case of the fur-cutter. She also was engaged in the carding of Russian hair.

These cases occurred in the same factory which furnished the outbreak of March, 1878; but there are two other similar factories in Glasgow, and I find evidence pointing strongly to the conclusion, that in one of those also there have been deaths from internal anthrax, while in the other, so recently as last August, two cases of undoubted external anthrax occurred (28). In both cases "raw Russian manes" were, at the time of these illnesses, in process of manufacture, and the persons attacked were engaged in picking and sorting the hair. In the latter case this hair was very manifestly charged with crude impurities of various kinds, both animal and vegetable.

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XXI.—*The Mud of the Clyde.* By DR. R. ANGUS SMITH, F.R.S., &c., Manchester.

[Read before the Society, May 5th, 1880.]

SOME years ago I sent to this Society a short paper on the Water of the Clyde. I could not give much time to it, but I had specimens, to the number of 45, collected from 6½ miles above Glasgow and downwards, whilst some were taken beyond the Clyde, on the steamer track to Liverpool. The specimens were small; I tried only the capability of absorbing oxygen from permanganate. I know well that the value of this test has been spoken against, but it is no less certain that putrifying organic matter gives out gases rapidly acted on by permanganate of potash, and whilst they exist they show themselves by their destruction of colour. Observing this loss of colour we may be quite sure that we are measuring something that pure water does not contain.

The amount of oxygen taken up instantly by water at the Broomielaw, Glasgow, was 15·4 grains per 100 gallons; opposite Lamlash, and onwards in the Irish Channel, only ·35. Near the Isle of Man it rose a little; between Inverkip and Cumbrae Lighthouse it varied between 0·35 and 0·7. The number 0·7 represents the Firth of Clyde, and lochs opening into the Clyde, and 0·35 the sea. A clear stream between Innellan and Dunoon gave 0·35, like the sea.

We may say that the sea and pure streams are represented by 0·35, when the water at Inverkip and below is more properly represented by ·70; the streams, however, and their neighbourhood being, like the pure sea, ·35.

	Time.	Oxygen per 100 gallons required to oxidize the decomposed organic matter.
	Aug. 15, '66.	
6½ miles above Glasgow, ...	3.30 p.m.	3·15
5½ miles above Glasgow, ...	3.15 ,,	4·55
5 miles above Glasgow, Cambuslang, ...	3 ,,	5·95
Broomielaw, ...	1.30 ,,	15·40
Mouth of Kelvin, ...	1.20 ,,	11·55
100 yards below Renfrew, ...	1 ,,	10·85
100 yards below Bowling, ...	12.45 ,,	4·55
At Dumbarton, ...	12.30 ,,	4·55
Between Greenock and Port-Glasgow,	12.10 a.m.	3·15

	Time.	Oxygen per 100 gallons required to oxidize the decomposed organic matter.
	July 25, '66.	
Gourock, ...	12.55 p.m.	1·05
Cloch, ...	12.45 ,,	1·05
Inverkip, ...	12.30 ,,	0·70
Wemyss Bay, ...	12.15 ,,	0·35
Opposite Toward, ...	12 noon	0·70
Between Toward and Cumbrae, ...	11.30 a.m.	0·70
Opposite Cumbrae Lighthouse, ...	11 ,,	0·70
Opposite Lamlash, ...	10.15 ,,	0·35
	July 25, '66.	
188 miles from Liverpool, ...	10 a.m.	0·35
176 ,, ,, —Ailsa Craig,	9 ,,	0·35
160 ,, ,, ...	8 ,,	0·35
131 ,, ,, ...	6 ,,	0·52
103 ,, ,, ...	4 ,,	0·52
74 ,, ,, —North of Isle of Man,	2 ,,	0·70
	July 24, '66.	
46 miles from Liverpool, ...	12 night	0·87
32 ,, ,, ...	11 p.m.	0·87
17 ,, ,, ...	10 ,,	1·05
	Aug. 13, '66.	
Off Greenock, ...	5.10 p.m.	1·40
	Aug. 15, '66.	
Off Helensburgh, ...	6.35 p.m.	0·875
	Aug. 13, '66.	
Off Gourock, ...	5 p.m.	1·22
Between Kirn and Gourock, ...	6 ,,	1·22
	July 30, '66.	
Arrochar (Loch Long), ...	1.30 p.m.	0·70
	Aug. 15, '66.	
Off mouth of Loch Long, ...	6.55 p.m.	0·875
	Aug. 17, '66.	
Head of Loch Goil, ...	1.5 p.m.	0·875
Entrance of Loch Goil, ...	4.30 ,,	1·05
	Aug. 1, '66.	
Head of Holy Loch, ...	2.45 p.m.	0·70
Middle of Holy Loch, ...	2.30 ,,	0·52
	July 31, '66.	
Dunoon (several 100 yards from shore),	1 p.m.	0·70
Dunoon (about 800 yards from shore),	1.15 ,,	0·70
	Aug. 16, '66.	
Off Dunoon, ...	1 p.m.	0·70
Stream at West Bay, Dunoon, ...	1 ,,	0·52
Stream between Innellan and Dunoon,	12 noon.	0·35

	Time.	Oxygen per 100 gallons required to oxidize the decomposed organic matter.
	Aug. 16, '66.	
Between Innellan and Dunoon,	1.8 p.m.	0·875
Off Innellan,	1.15 ,,	0·70
	Aug. 9, '66.	
Off Wemyss Bay (high tide),	12 noon.	1·05
Off Wemyss Bay (low tide),	4.30 p m.	0·875

The water at the Broomielaw, Glasgow, being 15·40, we may put these into more convenient figures, and calling the amount in the wide sea 1, we have the following Table :—

Table I.

	Time.	Oxygen per 100 gallons required to oxidize the decomposed organic matter.
6½ miles above Glasgow, August 15th '66,	3.30 p.m.	9
5½ miles above Glasgow,	3.15 ,,	13
5 miles above Glasgow, Cambuslang,	3 ,,	17
Broomielaw,	1.30 ,,	44
Mouth of Kelvin,	1.20 ,,	33
100 yards below Renfrew,	1 ,,	31
100 yards above Bowling,	12.45 ,,	13
At Dumbarton,	12.30 ,,	13
Between Greenock and Port-Glasgow,	12.10 a.m.	9
Gourock, July 25th, '66,	12.55 p.m.	3
Cloch,	12.45 ,,	3
Inverkip,	12.30 ,,	2
Wemyss Bay,	12.15 ,,	1
Opposite Toward,	12 noon	2
Between Toward and Cumbrae,	11.30 a.m.	2
Opposite Cumbrae Lighthouse,	11 ,,	2
Opposite Lamlash,	10.15 ,,	1
188 miles from Liverpool, July 25th, '66,	10 ,,	1
176 ,, ,, —Ailsa Craig,	9 ,,	1
160 ,, ,,	8 ,,	1
131 ,, ,,	6 ,,	1·5
103 ,, ,,	4 ,,	1·5
74 ,, ,, —North of Isle of Man,	2 ,,	2·0
46 ,, ,, —July 24th, '66,	12 night	2·5
32 ,, ,, ,, ,,	11 p.m.	2·5
17 ,, ,, ,, ,,	10 p.m.	3·0
Off Greenock, August 13th, '66,	5.10 ,,	4
Off Helensburgh, August 13th, '66,	6.35 ,,	2·5
Off Gourock, August 13th, '66,	5 ,,	3·5
Between Kirn and Gourock, Aug. 13th, '66,	6 ,,	3·5

	Time.	Oxygen per 100 gallons required to oxidize the decomposed organic matter.
Arrochar, Loch Long, July 30th, '66, ...	1.30 p.m.	2·0
Off mouth of Loch Long, Aug. 15th, '66,	6.55 ,,	2·5
Head of Loch Goil, Aug. 17th, '66, ...	1.5 ,,	2·5
Entrance of Loch Goil, ...	4.30 ,,	3·0
Head of Holy Loch, Aug. 1st, 66, ...	2.45 ,,	2·0
Middle of Holy Loch, ...	2.30 ,,	1·5
Dunoon (several 100 yards from shore), July 31st, '66, ...	1 ,,	2·0
Dunoon (about 800 yards from shore), ...	1.15 ,,	2·0
Off Dunoon, Aug. 16th, '66, ...	1 ,,	2·0
Stream at West Bay, Dunoon, August 20th, '66, ...	1 ,,	1·5
Stream between Innellan and Dunoon, ...	12 noon	1·0
Between Innellan and Dunoon, ...	1.8 p.m.	2·5
Off Innellan, August 9th, '66, ...	1.15 ,,	2·0
Off Wemyss Bay (high tide), ...	12 noon	3·0
,, ,, (low tide), ...	4.30 ,,	2·5

This Table tells a great deal. It shows that the water of the Frith, even up to Dunoon, is not affected to any very appreciable extent by the Glasgow Sewage in ordinary times, and if the water is so little affected, still less must the air be. We are now able to see the great advantage gained by the settling down of the mud, and its removal by boats above and opposite Greenock; as also by the great oxidation which takes place between Gourock and Dumbarton. It would be a most fortunate thing if the whole Clyde, at Cardross, were both wider and deeper; it would then be a still better place of deposit, and it would not greatly affect the air. It would probably be affected less than it is at several points at present, because there would be less concentration. It would relieve Helensburgh, Greenock, and Gareloch, as well as all the Firth. There are men who would willingly see the opposite take place, and fill up the space so as to lengthen the narrow stream or river bed. This would keep it filthy as far as Greenock, or farther, according to the breadth. This would render the climate inferior from Dumbarton downwards, and throw the present deposits on Dunoon and the Argyle coast: that is supposing the present solid matters to be sent down from Glasgow. But even if this did not continue, the natural deposits from Clydesdale would still exist, and in floods they are heavy. The mud during these floods is yellowish, and not so impure as the Glasgow mud, but we could never expect it to be so pure as not to injure the water of the coast-line where t first strikes. Besides, we know that the junction of the salt and resh water is never quite so agreeable as those spots where they re separate, although this is not much observed in a northern limate, and may almost be left out of consideration with us. This is said not merely in a sanitary point of view. Looking on he whole Firth, with its lochs, as the sanatorium of South-west Scotland, it is desirable to preserve the river-form or sailing hannel as far up the Clyde as possible. The more we push the eposits out to sea, the less do we allow harbour room for our vessels; and we must look, if not to distant posterity, at least to ur immediate successors. If we do not take care we may injure ur roadstead at Greenock, and diminish the shelter now obtained from a south-west wind by driving the vessels outwards for anchorage.

It cannot be doubted that the whole drainage land of Clydesdale, s well as the towns, affects the water, and it is interesting to know how much is owing to Glasgow. In the tables of analyses the numbers which have been given have no relation to the total amount of mud in the river; this information is best obtained from the River Trustees, and at present I am writing entirely in ignorance of it. This inquiry is simply an extension of the former paper, which looked to the oxidation at the surface, and I now look to the oxidation below. For the purpose of obtaining specimens, I asked my friend, Mr. James Duncan, of Benmore, to allow his steam yacht to be used; and with this request he readily complied, and did me the favour of coming himself and looking after the operations.

The specimens were various in appearance. Some were stoney, some muddy; some had life in them, chiefly star fishes; and some of those which were very muddy were entirely free from any living things visible to the naked eye. The first thing to decide was—What is mud? and this question was answered in the following manner to suit the circumstances:—The material collected, which, in every case, was preserved in a well-stoppered bottle, holding 280 c.c. or 10 ounces, was stirred up in a sufficiently large beaker, and allowed to stand seven minutes. The liquid was then carefully poured off, and more water added, until the washings were clear. The latter washings required only three minutes, as in that time all that would fall at all had been deposited—a minute portion excepted, too tedious to wait for, or incapable of altering any figures given. The effect, if appreciable, would be in smaller decimals than those used.

The following Table shows the results in the order of the quantity of mud in the amount dredged up:—

TABLE I.

Percentage of the mud in dredgings from the Firth of Clyde.

	Per cent.
In the Channel above Port-Glasgow.	0·5
Half-way between Port-Glasgow and Dumbarton.	0·6
Off Caird's Building Yard.	1·6
[illegible], Wemyss Bay.	2·9
One-third across from Inverkip.	3·0
Off [illegible] Green [illegible].	3·6
[illegible]	6·3
[illegible] Bay.	9·5
Half-way between [illegible] and Little Cumbrae.	9·5
Inverkip.	10·2
[illegible] [illegible] Chapel, Wemyss Bay	12·1
Half-mile from [illegible].	14·3
In centre of [illegible] Bay.	14·9
Off Bogany.	15·9
Half-mile from south end of Little Cumbrae.	29·5
North end of [illegible] Bay.	29·6
Two-thirds across from Inverkip.	29·6
Above the Narrows.	29·9
Quarter-mile from [illegible] Beacon.	34·38
Off centre of [illegible] Bay.	35·10
Off Ardmore Point.	39·9
Off Cairn Dhu Point.	40·9
Off Garvel Dock.	41·9
One mile east of [illegible].	42·3
Strone Point, Loch Striven.	43·6
One-third from Rosneath to Powder Buoy.	53·6
One-third from the "Cumberland" towards Rosneath Castle.	58·3
Half-way between Tail of Bank Buoy and Helensburgh.	58·6
At [illegible], Helensburgh.	66·1
Quarter-mile from Camus Eskan House.	68·6
Close to Tail of Bank Buoy.	76·2
Off Ardencaple [illegible].	80·5
Abreast of Clynder.	91·9
Two miles south of the west part of Little Cumbrae.	97·5

On Table III. we have the quality of the mud given in relation to volatile matter and fixed matter. It must be remembered that this does not relate to the whole material dredged up, but only to the amount explained to mean mud, and which, in some cases, was seen to be very low—viz., as far down as a half per cent. The variations here are not great, but enough is shown to satisfy one he organic matter is very much removed from the mud when hes below Greenock, and even near the pier at Helensburgh, the first dredge on that shore was taken.

TABLE III.

Mineral and volatile matters in fine mud from the Clyde.

Locality.	Percentage.	
	Volatile Matter.	Mineral Matter.
nnel above Port-Glasgow, ...	—	100·0
he west part of Little Cumbrae, ...	4·28	95·72
bruaich, ...	4·46	95·54
dge, Helensburgh, ...	4·72	95·28
the Gantocks, ...	5·31	94·69
r mile from Innellan Beacon, ...	5·50	94·50
re of Row Bay, ...	7·47	92·53
tre of Gourock Bay, ...	7·48	92·52
r mile from Camus Eskin House, ...	8·12	91·88
le east of Kingarth, ...	8·26	91·74
lencaple Toll, ...	8·93	91·07
glish Chapel, Wemyss Bay, ...	9·09	90·91
ile from Mount Stuart, ...	9·18	90·82
Point, Loch Strivan, ...	9·30	90·70
ay between Portincross and Little Cumbrae,	9·58	90·42
ird from Roseneath Castle to Powder Buoy,	9·60	90·40
rn Dhu Point, ...	9·70	90·30
ay between Tail of Bank Buoy and Helens- rgh, ...	10·23	89·77
ird from the "Cumberland" towards Rose- ath Castle, ...	10·37	89·63
end of Row Bay, ...	10·37	89·63
lmore Point, ...	10·90	89·10
irds across from Inverkip, ...	11·06	88·94
o Tail of Bank Buoy, ...	11·19	88·81
t of Clynder, ...	11·20	88·80
vel Dock, ...	11·25	88·75
Bay, ...	11·89	88·11
h Green Gas-works, ...	13·08	86·92
o Govan Dock, ...	13·38	86·62
ird across from Inverkip, ...	14·73	85·27
ip, ...	15·60	84·40
ay between Port-Glasgow and Dumbarton,	22·22	77·78

le No. II. shows that the navigable channel of the Clyde Greenock is well cleared of mud. The cause of this is pro- twofold—we have the scouring of the tide and the continual of the steamers keeping the lighter matter in suspension aving the heavier to the operations of the dredging machines.

It is, however, surprising to see the upper part of the river so clear. The mud then deposits itself in various spots, depending partly on currents and partly on depths. It seems to run down very freely below Greenock, but the returning tide sends it back, and we have it thrown up to a great extent, I believe, against the northern shore. The action of the currents from above Greenock and from the sea together are inclined to drive it in towards Gareloch, and probably much into the loch itself a short way; and when there it cannot return. I do not know how much will be driven up Loch Long, but I think there must be little, and the deposit which is systematically made there by the vessels which carry into it the dredged up mud, will prevent this question being easily answered. When examining the surface water it was found that the north side was better than the south, from Gourock and some distance down.

The mud below does not correspond with the quality of the water above, except in very shallow places.

The long stretch of water lying between Ardmore and Dumbarton is not all an accumulation of mud, which is an indication that the mud falls down and is carried off mainly by the deep channels. The channel is inclined to act as a depositing reservoir, and the northern side receives the overflow water. The mud remaining in the channel is carried partly by nature, and as the water leaves the channel it becomes less disturbed and clearer. This water has, of course, some of the lighter and the soluble parts which the putrefying river brings down, but it really seems as if a very large portion of this were rapidly oxidized, and, whilst the neighbourhood is freed from the mud which might continue sending out more gases, the water is rapidly undergoing purification, and it flows then down as the tide goes out, bringing unexpectedly good water below, although, of course, not perfect. We see a rapid change of water about this district.

I feel inclined, therefore, to repeat that this space is of great value to all the watering-places of the Clyde, and if it is ever made into arable land, they will suffer severely. I only wish it were still larger. There was a time when it was supposed to be much deeper than at present, because of the choice of Cardross by King Robert Bruce as a residence, where he delighted in building—let us say yachts—and in sailing. I do not know how far this diminution of depth may have taken place, but it is quite clear that it did not extend over all the part which the tide covers, because we see large and even moderately small stones lying on the surface at a considerable distance from the northern shore. There may, however, be a narrowing of the channel, increasing the banks close to the channel, and raising them. This quite agrees with my other idea that the water, after depositing some mud, rises over the bank much purer, and it moves on, probably becoming constantly purer as it passes to the Cardross shore. It seems to me that the centre bank is higher than it was in my boyhood. If the water were prevented from flowing over to the present north shore there would be not only less purification by oxidation, but the amount for scouring the navigable channel would be greatly diminished. I fear we must forego the great advantage of having the whole deepened, and the hope of some natural scouring process made use of for this purpose. The Ardmore point protects the Cardross shore, diverting the rush of water. If there were no tides the flow would, I suppose, be onwards to the Dunoon shore—a constant flow of fresh water keeping it from entering the sea lochs; but, when driven back, it is again stopped by Ardmore, and a deposit takes place between that and Roseneath, whilst some is driven up the Gareloch, in which it must deposit, with little chance of returning. There can be no doubt that the mud is of a less oxidized kind in the middle, off Clynder, and, I suppose, therefore not very old; but I have not examined the shallow parts where, if deposited, it might affect the air, as I saw no reason for suspicion. It must, however, be asked, if we have touched on the only cause? Could the drainage of the habitations on the loch not account for the whole deposit after many years of occupation?

This case can be answered at present only by an opinion, and my opinion is that it cannot be. I think we may see the yellow-brown water of the Clyde during a flood driven up towards the mouth of the loch; and the Row Bay has had for many years a not very agreeable smell. That this smell is increasing is my opinion; but of course it is only an opinion. I did not go there in childhood. However, there is one cause that will assist the pollution of the Gareloch to a considerable extent, and that is the "Cumberland" training-ship. Of course this may be objected to, and one may say—Are there not on the sides of the loch more inhabitants than in the ship, and why bring a severe complaint against the vessel? I do not make the complaint severe, but we must consider that the refuse of all the houses on the loch does not go into it, although in most cases it ultimately [illegible] the sewage from 340 of the ship should be [illegible] at the [illegible] middle of the entrance to the loch, [illegible] opportunity of [illegible] representing a condition [illegible] different from that of the loch. On the other hand, [illegible] the 300 [illegible] the shores, if all their sewage [illegible]. The neck of the loch is narrow, and [illegible] the [illegible] natural [illegible] but the [illegible] must be made by considerable force, [illegible] will produce a deposit [illegible]. I cannot enter [illegible] as the [illegible] the narrow neck is passed. [illegible] the shores are inhabited [illegible] they are made into harbours, [illegible] at some time, unless special [illegible]. And what is [illegible] without a serious amount [illegible] to purify perfectly. It is [illegible] matter escaping from every individual [illegible] and for this reason cannot [illegible] possible by the daily flow of sea water and fresh water. [illegible] is true that the organic matter is [illegible] of the loch, and that the main [illegible] of its shores the admixture of some [illegible] sewage [illegible] but until we know how much is sent down [illegible] it would be unwise to change. There might be an [illegible] the flow of sewage [illegible] as well as the training-ship, take [illegible]. Some such [illegible] would do some good of a [illegible] they have the disadvantage of [illegible] tending to [illegible], and using the oxidising action of the [illegible], which, acting in the same direction as the space between Greenock and Dumbarton, is a fine open space, into which pure fresh water is poured in considerable amounts, and which is large enough not only to purify all its own surface, but to affect the water outside also. But I am going on the supposition that the [illegible] of these seas is injurious—and what proof is there? If we go to the shores of Lamlash Bay, near the [illegible], and far from the houses, where the water is perfectly pure to all appearance, and dig six inches into the sand, we find a greenish mud with a putrid smell; and so it is, I believe, on many shores. Purity is quite close to impurity; and what is wholesomer than a garden where the leaves oxygenate the air, and where certainly men may live long days in air of the sweetest kind, and yet, if we scratch the ground a few inches, we are horrified with many disagreeable things. If we escape into the wider fields we are not quite free from troubles—we must not put our mouths to the ground. A few inches of soil are a perfect protection from most evils, if not from all, in the shape of emanations; and is not the same to be got by several fathoms of water? I believe it is, and I would not care to disturb my mind or yours about mud lying quietly under such circumstances; but, if the mud be merely an indication that a certain amount is continually depositing itself from the water, then matters are different, and the mud becomes an indication of the state which the water will attain, according to depth and motion. We must remember that the idea of depth must be taken in when we consider its effect on a spot, but it has no meaning where the mud is apt to be stirred up either by currents, waves, or steamboats, as then it is the same at the surface as below, or nearly so. I should like much to know the condition of Loch Long, and it is my own fault that it has not been attended to, I suppose, if it is a fault not to be able to do all that we intend.

TABLE IV.

Ammonia in dry mud from deposits in the Firth of Clyde.

A

	Per cent.
In the Channel, above Port-Glasgow, ...	0·0324
Off Inch Green Gas-works, ...	·0615
Two miles south of the west part of Little Cumbrae,	·1069
Above the Gantocks, ...	·1760
One-third from the "Cumberland" towards Roseneath Castle, ...	·1804
Off Cairn Dhu Point, ...	·1953
One mile east of Kingarth, ...	·2241
Half-mile from south end of Little Cumbrae, ...	·2282
Off centre of Gourock Bay, ...	0·2292
Two-thirds across from Inverkip, ...	·2304
Close to Tail of Bank Buoy, ...	·2529
Half-mile from Mount Stuart, ...	·2570
Off Bogany, ...	·2615
Quarter-mile from Innellan Beacon, ...	·2628
Quarter-mile from Camus Eskin House, ...	·2654

B

	Per cent.
Half-way between Tail of Bank Buoy and Helensburgh,	·3086
Off Ardencaple Toll,	·3095
One-third across from Inverkip,	·3101
Opposite English Chapel, Wemyss Bay,	·3169
Inverkip,	·3201
One-third from Rosneath to Powder Buoy,	·3207
Abreast of Clynder,	·3223
Strone Point, Loch Striven,	·3256
Half-way between Portincross and Little Cumbrae,	·3300
Off Garvel Dock,	·3632
In centre of Row Bay,	·3702
North end of Row Bay,	·3704
Off Laird's Building Yard,	·3840
1st Dredge, Helensburgh,	·4045
Off Ardmore Point,	·4184
Ettrick Bay,	·4312
Half-way between Port-Glasgow and Dumbarton,	·7380
Tighnabruaich,	·8214
Opposite Govan Dock,	·9734

TABLE V.

Phosphoric Acid in mud from deposits in the Firth of Clyde.

A

	Per cent.
In the Channel above Port-Glasgow,	—
1st Dredge, Wemyss Bay,	—
Off Cairn Dhu Point,	0·0381
Off centre of Gourock Bay,	·0528
Half-mile from south end of Little Cumbrae,	·0917
Above the Gantocks,	·0956
Two miles south of the west part of Little Cumbrae,	·1124
Ettrick Bay,	·1161
Half-way between Tail of Bank Buoy and Helensburgh,	·1181
Half-mile from Mount Stewart,	0·1234
One mile east of Kingarth,	·1263
Two-thirds across from Inverkip,	·1300
Off Bogany,	·1312
Quarter-mile from Innellan Beacon,	·1487
One-third from the "Cumberland" towards Roseneath Castle,	·1527
Off Garvel Dock,	·1620
Off Ardencaple Toll,	·1635
Quarter-mile from Camus Eskin House,	·1640

B

	Per cent.
Off Inch Green Gas-works, ...	·1803
Strone Point, Loch Strivan, ...	·1816
Off Ardmore Point, ...	·1846
One-third from Roseneath Castle to Powder Buoy,...	·1878
Opposite English Chapel, Wemyss Bay.	·2001
Close to Tail of Bank Buoy, ...	·2069
Half-way between Portincross and Little Cumbrae,	·2107
In centre of Row Bay, ...	·2082
Tignabruaich, ...	·2260
One-third across from Inverkip, ...	·2270
Inverkip, ...	·2421
North end of Row Bay,...	·2603
Half-way between Port-Glasgow and Dumbarton, ...	·2616
Off Caird's Building Yard, ...	·2647
1st Dredge, Helensburgh, ...	·2763
Abreast of Clynder, ...	·2769

he mud in some places, as far as Little Cumbrae in the Firth, tains a good deal of nitrogen in deep spots, but even where p, if very fine in division, we did not observe life. In some es the number of star-fishes was surprising, especially on the th-west side of Bute. When the mud is very fine and full of ogenous matter ready to putrefy or putrefying, there is no earance of life, that is—to the unaided eye. Even the lowest ns are destroyed. I certainly expected more ammonia from e of the mud about Greenock and Port-Glasgow, and do not sufficiently the cause of its absence; however, we must decide t, in the centre of the channel at least, the constant stirring by mers, the natural flow, and the dredging carry it off. I do suppose that dredging alone could account for all this. We then, that at the expense of keeping the surface water less pure, bottom is purified and *vice versa* when no interference takes place. here can be no doubt that the Roseneath, Clynder, and ensburgh department is receiving more than its full share of deposit in a condition which we are inclined to object to. d yet the current deposits the matter curiously. The deposit ot so great at the north end of Row Bay as in the middle, and n we view the rapid rush of water there at times we can unt for it. There are other places also which may be found with similar characteristics.

Ve have now to examine more carefully into the nature of this nic and volatile matter. The following Table gives the ammonia. I have called it ammonia, although, of course, it does not exist as such, and is only *possible ammonia;* but it is a well known term, and as the nitrogen comes off to a great extent in the form of ammonia, when putrefaction takes place, I prefer the word for general use:—

TABLE VI.

Ammonia in 100 parts of deposit from the Firth of Clyde.

	Per cent.
A	
In the Channel above Port-Glasgow,	0·00017
Off Inch Green Gas-works,	·00225
Off Caird's Building Yard,	·00433
Half-way between Port-Glasgow and Dumbarton,	·00447
Off Cairn Dhu Point,	·00799
One-third across from Inverkip,	·0110
Tighnabruaich,	·0281
Ettrick Bay,	·0317
9. Half-way between Portincross and Little Cumbrae,	·0338
1st Dredge, Wemyss Bay,	·0355
Half-mile from Mount Stuart,	·0365
Inverkip,	·0368
Opposite English Chapel, Wemyss Bay,	·03937
Half-mile from South end of Little Cumbrae,	·0467
In centre of Row Bay,	·0510
Two-thirds across from Inverkip,	·0550
Above the Gantocks,	·0567
B	
North end of Row Bay,	·0761
Off centre of Gourock Bay,	·0846
Quarter-mile from Innellan Beacon,	·09293
One mile east of Kingarth,	·0982
Two miles south of the west part of South Cumbrae,	·1051
One-third from the "Cumberland" towards Roseneath Castle,	0·1151
Strone Point, Loch Strivan,	·1420
Off Garvel Dock,	·1614
One-third from Roseneath Castle to Powder Buoy,	·1689
Quarter-mile from Camus Eskin House,	·1717
Half-way between Tail of Bank Buoy and Helensburgh,	·1773
Close to Tail of Bank Buoy,	·1930
Off Bogany,	·2092
Off Ardencaple Toll,	·2496
1st Dredge, Helensburgh,	·2786
Off Ardmore Point,	·2976
Abreast of Clynder,	·2985
Opposite Govan Dock,	·5335

TABLE VII.

Phosphoric Acid in 100 parts of deposit from the Firth of Clyde.

A	Per cent.
1st Dredge, Wemyss Bay,	none
In the Channel above Port-Glasgow,	none
Half-way between Port-Glasgow and Dumbarton,	0·0030
Off Caird's Building Yard,	·0042
Off Inch Green Gas-works,	·0066
One-third across from Inverkip,	·0068
Ettrick Bay,	·0111
Half-mile from south end of Little Cumbrae,	·0119
Off Cairn Dhu Point,	·0156
Tignabruaich,	·0179
Half-mile from Mount Stuart,	·0182
Half-way between Portincross and Little Cumbrae,	·0202
Off centre of Gourock Bay,	·0210
Opposite English Chapel, Wemyss Bay,	·0241
Inverkip,	·0255
Two-thirds across from Inverkip,	·0292
Above the Gantocks,	·0294
In centre of Row Bay,	·0310

B	
North end of Row Bay,	·0536
One mile East of Kingarth,	·0537
Off Garvel Dock,	·0668
Half-way between Tail of Bank Buoy and Helensburgh,	·0692
Quarter-mile from Innellan Beacon,	·0531
Off Ardmore Point,	·0737
Strone Point, Loch Strivan,	0·0792
One-third from the "Cumberland" towards Roseneath Castle,	·0889
One-third from Roseneath Castle to Powder Buoy,	·1006
Two miles South of last from the west part of South Cumbrae,	·1093
Quarter-mile from Camus Eskin House,	·1102
Off Bogany,	·1103
Off Ardencaple Toll,	·1232
Close to Tail of Bank Buoy,	·1580
1st Dredge, Helensburgh,	·1827
Abreast of Clynder,	·2545
Opposite Govan Dock,	·3540

Tables IV. and V. give the ammonia and phosphoric acid in the "mud," but the mud varies in amount. It is therefore better to give other Tables, showing the amount of these bodies in the entire deposit. This is, of course, much lower. For this purpose Table VI. is given, showing the amount of ammonia in the whole deposit, and Table VII. the amount of phosphoric acid in the whole deposit.

As phosphoric acid, like ammonia, is necessary for animal life, and, like nitrogen, is found in all excreta of animals, we may look to it as an important indication of quality, although it is less active in its movements and decompositions. On Table V. we see that the order is very nearly the same as the order of the names in the ammonia Table IV. The ammonia and the phosphoric acid have each been divided into two groups, the higher and the low numbers. The division was made at points where a considerable leap occurred: for example, in the case of ammonia, from ·0567 to ·0761, and in the case of phosphoric acid, from ·031 to ·0536. It will be found that, with one exception, every name occurring in the high column in one, occurs in the high column in the other. This exception is "off centre of Gourock Bay." This shows a remarkable constancy, and also a proof of correctness. If, however, we compare the amounts of nitrogen and phosphorus, we find them approaching rather closely; and this shows that, as we might expect, more ammonia escapes than phosphoric acid, so that the percentage of ammonia diminishes, and that of phosphoric acid, by diminishing less, is brought nearer. The amount of nitrogen in sewage is far beyond the amount of phosphorus.

And now, after all, what is the use of this knowledge? We cannot tell all its use. Already we all know that the less we send down the Clyde the better for the inhabitants of the shores. It is a great advantage at present that the Clyde above Greenock is so stirred up; the organic substances putrefy violently when kept in suspension and warmed by the weather, instead of lying at the bottom, sending up occasional and worse gases when moved. The channel, especially from Glasgow to Dumbarton, is the part where the gases are perceptibly given off, and where the organic substances are broken up into such fragments that the most offensive matter almost ceases to offend, and germs of disease themselves are broken into pieces and scattered partly as pure gases into the atmosphere and partly as mere mud to the bottom. There is no purifier like putrefaction. The vilest filth under its influence ceases to be filth, and, although the immediate neighbourhood may be offensive, we go off a little distance and perceive nothing. And yet, whilst I write, I am almost hearing this fact questioned, for, after all, it is only true in some places. The decompositions which attend putrefaction in warm moist places must be very different from those which take place with us. The heat seems to allow the escape of bodies farther advanced in organization than those which occur with us. In hot countries germs of fevers escape, whilst we have chiefly, but not entirely, inorganic gases. This raises a question to be solved, but the fact is certain that fevers have not been traced to the escape of gases of putrefaction when there has been a large amount of water and exposure to the air. But they have been found when the water is not very great in amount, and the decomposition is made under cover, as in sewers. The question arises—Is this owing to the concentration, or to the difference of decomposition in darkness, or to the better supply of oxygen? The effect of sunlight in warm countries does not allow us to suppose that the daylight always produces in vapours an innocent state, although it has a great effect in that direction when there is little water. With us, at least, innocence in the atmosphere seems to be rather something connected with the abundance of air in proportion to the impurity. This air again may act in two ways. It may act by rapid oxidation of the substances in water, or by dilution of the gases when formed; and the destruction of putrid matter in water is really very rapid when plenty of air is allowed. This air is brought to the Clyde by the water, and also by the waves, both artificial and natural, exposing a great deal of surface. The air may act also merely by rapid dispersion of the gases. Still we must not forget that these gases or vapours are not reported to us to produce any marked type of disease over the Clyde, even when they come in a state so concentrated as to produce sickness, whereas gases from sewers, in a condition which may not produce immediate illness, may produce in time typhoid fever, as we are credibly informed.

We must conclude, then, that it is not mere dispersion, but that it is a more thorough putrefaction and oxidation which takes place in the Clyde, and a more complete destruction of the organic substance by the abundance of air, than can take place in sewer water, whatever the senses may indicate to us. Of course we must ever give some credit to the flow of air up the river, and the ever-fresh breezes that come from the Atlantic, as well as the mixture of air with water caused by steamers.

Whilst then there is oxygen enough at present to prevent disease, there is not enough to prevent smells which disgust and cause sickness for the time.

All this seems clear. The novelty is chiefly here seen in pointing out the places where the under-currents of water are insufficient to remove the mud, and where the under-currents have not sufficient air to purify the putrefiable matter. But even this is imperfectly done, and the best use I can see for my work is to show a method of observation, which has not, so far as I know been applied to any river in its whole extent. The work may be extended and repeated so as to show more minute details. It may also help to put us on our guard against encroachments of the sewage on the health grounds below, so important to the people of Glasgow, so pleasant to the young, and so valuable also to those who would not for their own sake go out of town, but who are, fortunately for themselves, compelled to go for the sake of their families.

It may be supposed that I have more interest in seeing the Lower Clyde pure than that between Dumbarton and Glasgow, which, after all, is the part which alone smells badly. This is partly true, the case is there so clear that a remedy will be urged by everyone, and although I understand that no actual disease has been traced to its influence, I will not believe that it is quite innocent, or that it is not to some extent injurious to health. We have, unfortunately, been too much accustomed to measure health by the percentage of deaths, a method useful certainly and especially valuable, as showing the effects of seasons, the insidious beginnings, and the progress of epidemics and any unusual or uncertain influence, but unfitted for showing the amount of vitality in the adults of a population, and for measuring the vigour of the people's life. A plan for this is very much wanted, and our Tables of Deaths are already getting old-fashioned and wearisome, being void of that very meaning which is most desired.

The waters examined in 1866 were collected by my nephew, Alfred Mica Smith, B.Sc., at present of the School of Mines, Sandhurst, Victoria. The want of phosphoric acid above Port-Glasgow must be in some exceptional specimen.

XXII.—*Sewage, Sewerage, and Drainage, Scientific and Sanitary,* versus *Unscientific and Unsanitary Sewerage and Drainage; with an Exposition of the New Pneumatic (Shone's) Sewerage System.* By Mr. ISAAC SHONE, C.E., F.G.S., Assoc.-Mem. Inst. C.E. (Ex-Mayor of Wrexham).

[Read before the Society, February 26th, 1880.]

To explain the *modus operandi* adopted by engineers when they are called upon to carry out drainage schemes upon the Gravitating Sewerage System *per se*, I will state, *seriatim*, in the form of questions, the salient points with which they would probably deal, preparatory to their submitting schemes that should pass muster with the Sanitary Authorities and with the Local Government Board. The order of the questions will also represent approximately the order in which these points would probably be considered:—

1. What is the present population of the town to be sewered?

2. What is the area which may fairly be considered as occupied by the present population, and which must, sooner or later, be sewered or drained into the system of drainage to be designed?

3. What has been the rate at which the population has increased, according to the censuses of 1861 and 1871?

4. Is it likely that the rate of increase revealed by the censuses of 1861 and 1871 will continue, or will it diminish or increase?

5. What is the average rainfall due to the district in which the town to be sewered or drained is situate, and what is the nature of the soil of the place, and the streets, &c., of the town? Will the soil largely absorb the rain as it falls, and is the town well paved or not, &c.?

6. Shall the sewerage system be designed in the meantime to provide for the transport of the sewage of the population which may grow up, say, in the next thirty years? And

7. Shall the system of sewers be made capacious enough, in the meantime, to take (1) the sewage of the population which may grow up within the next thirty years, and (2) the rainfall due to the area which would probably be occupied by the future population?

TABLE showing [illegible]

Population, [illegible], Sewage proper only, Rain-fall only, taking the maximum fall [illegible] in [illegible], and [illegible] Sewer [illegible], Rainfall and Sewage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10,000	[illegible]	[illegible]	[illegible]	[illegible]
				[illegible]	9,004	[illegible]	[illegible]	[illegible]	[illegible]	118,100	440·[illegible]	[illegible]·100	[illegible]	[illegible]
				[illegible]	8,204	[illegible]	[illegible]	31·[illegible]	[illegible]	128,100	407·00	23·108	601·78	[illegible]
Population, [illegible], Sewage proper only, Rain-fall only, as above,	700	[illegible],871 [illegible]	[illegible]	110·40	[illegible]	12·[illegible]	2·057	10·[illegible]	2·[illegible]	27,010	217·10	10·724	307·71	15·166
		…		1,928·44	8,271	34·704	8·379	45·047	3·88	330,840	751·85	37·128	1,063·3	52·507
Rainfall and Sewage			…	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	792·58	38·646	1,106·7	54·653

After investigating the subject, as set forth above, the engineer would probably answer the last query (No. 7) in the affirmative, and proceed to adjust the sizes of his sewer-pipes accordingly.

The Table given on page 2, which is made to apply to a flat town of 250 acres in extent, with a present population of 10,000, will show approximately what would result from such a mode of procedure.

You will observe that the Table shows that a pipe of 9·1288 inches in diameter, *half-filled*, and laid at a gradient of 1 in 184·87, would suffice for the *sewage-proper* of the present population of 10,000, whereas, a pipe of 10·724 inches in diameter, *running full*, would be required for the sewage-proper of the future population of 27,616; but, inasmuch as the engineer has to provide for the sewage-proper due to the future population, as well as for the rain-fall due to the area upon which the future population would reside, he would probably fix upon an out-fall pipe, in the meantime, which should run full at the end of 30 years, when the maximum of both rain-fall and sewage was passing into and through it, at a velocity of 3 feet per second; in which case a pipe of 38·646 inches in diameter, laid at a gradient of 1 in 782·58, would be required.

Supposing we use round numbers, and say that the pipes abovenamed are 9 and 39 inches diameter respectively; then, if we put the 9-inch pipe—which will discharge at a velocity of 3 feet per second only when laid at a gradient of 1 in 185—at the gradient which gives the same velocity for the 39-inch pipe, viz., 1 in 782, the relative discharging capacities of these pipes would be in the ratio of the square root of the fifth power of the diameters ($\sqrt{d^5}$); and, if we make the calculation, we shall find that the smaller 9-inch pipe, laid at the gradient suitable to the larger pipe, will only discharge, *when running full*, the $\frac{1}{39}$th part of the volume of the sewage which would be required to create the 3 feet velocity in the 39 inch pipe! Hence, if we divide the volume of sewage due to the 39-inch pipe, when running full—which, as per Table, is 1434 cubic feet per minute—by (39 x 2) 78, we shall have the number of cubic feet which the 9-inch pipe would discharge, *running half-full*, and laid at the gradient of 1 in 782: this is equal to 18·4 cubic feet. Again, if we divide the latter quantity by half the sectional area of the 9-inch pipe = (18·4 ÷ ·22), we find that the lineal velocity due to the maximum flow of sewage in the 9-inch pipe would be 83·6 feet per minute, or 1·4 feet per second, instead of 180 feet per minute, or 3 feet per second, the velocity known to be needed to keep such a pipe self-cleansing and free from deposit!

It will be seen that, whilst a 9-inch pipe, *half-filled*, and laid at a gradient of 1 in 185, will act perfectly the part of a *sanitary sewage-carrier* for the *present* population of 10,000, it cannot possibly do so, nor can it take the quantity (40 cubic feet) when running full even, if we lay it at a gradient of 1 in 782. But, by introducing the maximum flow of sewage of 10,000 people—viz., 40 cubic feet per minute, as per Table—into a 39-inch pipe, laid at a gradient of 1 in 782, it is manifest that our 39-inch sewage-carrier, which is only suitable as such when the maximum sewage flow of a population of 27,616, together with the rain-fall due to the area estimated to be occupied by that increased population, will be discharged into it, would become a sewage stagnator; and, *ergo,* a sewage-gas generator! Under such conditions as these the sewage *must* decompose; in other words, it must, as it does in practice, in 95 cases out of every 100, part largely with its poisonous and manurial essence, before it reaches the out-fall.

In fact, I have no hesitation in stating that the wholesale and indiscriminate adoption of the mixed sewerage or drainage of this country, is not only the chief cause of our high death-rate, the cause of so much trapping of sewage and sewage-air, the cause of the choking and stoppage of sewer-pipes and drains, and the cause of so much crying out for ventilation, but it is also the cause of the pollution by sewage of our brooks, rivers, and sea-shores, and the primary cause, also, of failure in sewage-farming.

Thoughtful men of science and engineering have of late years advocated the adoption of what is called "the separate system of sewerage" as the remedy for insanitary drainage; but the "separate system" of drainage, as it has hitherto been promulgated, will *not* remedy the evil, if the hydraulic conditions, which are essential to sanitary drainage, or sewerage, cannot be complied with; and because they cannot be complied with in practice—*i.e.*, in the vast majority of cases—engineers resort to the system of sewerage and drainage represented by the foregoing Table, and which system I have taken the liberty of designating an unscientific and unsanitary system of sewerage, or drainage.

I am also an advocate for the "separate system" of sewerage; but I have devised means whereby that system can be set down and made to work *sanitarily right anywhere* and *everywhere*, without regard to the undulating, or low, or flat-lying nature of the town, village, or district to be sewered. The remedy *I have to suggest, therefore, for unsanitary drainage* is the adoption of my own *pneumatic* sewerage system; but to carry it *out properly, by rule*, the "separate system" of drainage is indispensably necessary; and, if so, it should be insisted upon *in all new building areas.* Where towns or villages are already sewered, if the Sanitary Authorities would have *sanitary* drainage, they should convert the present sewers into drains for the reception of manufacturers' waste liquids, and for surface (rain) and subsoil waters, and put a fresh system of small pipes for the sewage-proper. The rain-water and *harmless* waste fluids from manufactories, etc., I would pass into the brooks, rivers, and seas, *via* drains, but the genuine sewage-proper I would transport to land *via* sewers.

I do not approve of incurring enormous cost to abstract, by the "pail system," the solid excrement from the sewage; for, if we assume the sewage discharges of a population to average 15 gallons per head per day, as per Mr. John Phillips', C.E., estimate, then the solid excrement and urine combined, only form about 2 per cent. of the 15 gallons. The *solids* collected in the pails even with 15 gallons as the water supply, would not be 1 per cent. of the liquid sewage; and forasmuch as the remaining 99 per cent. would be practically as offensive and as difficult to deal with, sanitarily speaking, as if the solids were allowed to commingle with it, I think it is a mistake to separate the solid excrement for collection and disposal, apart from the other portions of domestic sewage.

I believe in adding the excrement and urine to the other domestic waste fluids, and reducing the volume of the latter as much as possible, and applying the whole to land as *liquid manure.*

You may clarify it and defecate it before applying it, if you like, because I agree with General Scott, C.B., and the engineer to the Lee Conservancy Board, Major Flower, C.E., that much good could be done in that way, in many places, as sewage so treated could be hosed on to our gardens even, without giving offence.

Where the town or village is favourably conditioned naturally for the adoption of the gravitating plan by itself, I should not, of course, think of introducing any other system as an auxiliary to gravitation.

An eminent sanitary engineer, Mr. Lemon, C.E.—who is also, I am pleased to say, a believer in the "separate system," and who is [illegible] of Southampton—in the presence of the [illegible] Borough Surveyor, and a number of [illegible] other members of the Southampton Board of Health, after the [illegible] had inspected the working of my Ventilator, [illegible] his belief in my system, by stating that [illegible] *to render* [illegible] *and resort to my system.*" [illegible] from its most ardent [illegible]

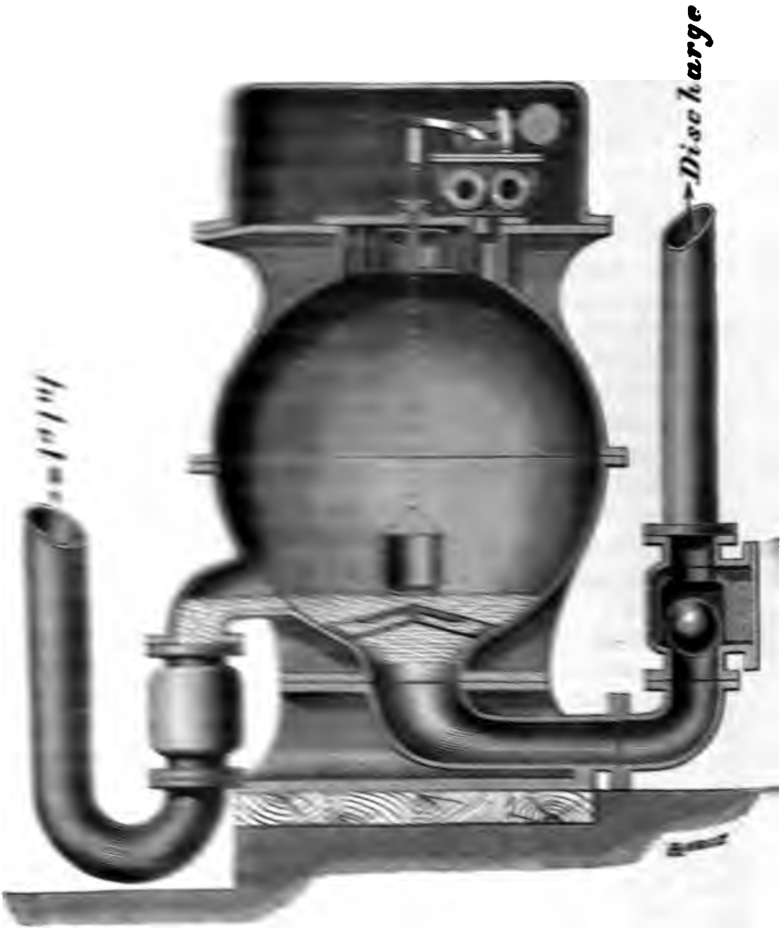
[illegible] will [illegible] and act as fairly [illegible] we shall soon see *practical examples* [illegible] *eagerly* [illegible] *depressed* [illegible].

I am [illegible] for the purchasing of good and sound materials [illegible] and I am [illegible] of the laying of sewer-pipes to [illegible] and [illegible] workmen. I should insist [illegible] and as uniformly even, as [illegible] railway. There should be the same amount of intelligent supervision and care with a system of sewer-pipes as there is with our railway systems, and until this is recognised [illegible] our sewer pipe-laying habits will [illegible] more people than all the railways and mines put together.

If a [illegible] of the line, a "Tay Bridge" gives way, or a colliery accident happens by which 200 or 300 lives are lost, on the [illegible] Europe's attention and sympathy is immediately aroused, and inspectors without number are sent upon the scene of the accident to inquire into the cause, &c., and if even excusable grounds can be set up to account for the disasters—if they can be regarded as strictly preventible accidents—the owners of the railway or the mine, or their managers and workmen, or both, as the case may be, are censured accordingly; and frequently verdicts of manslaughter are found against men for accidents, occasioned, possibly, through inexplicable, and it may be momentary aberrations on their part; and how many cases have occurred of late in which a doctor or a lawyer, or some other professional gentleman, whose life is valuable, having met with a railway accident, has been disabled from pursuing his business, and in consequence heavy damages—amounting, in some cases, to thousands of pounds—have been claimed by and paid to him. But a badly-drained and sewered town, with a population, say, of 20,000, will have a death-rate of, it may be, 5 or 10 per 1000 in excess of what it would stand at, if it were *sanitarily* sewered and drained; and of course you know this means, in a town with that population, that 100 or 200 lives are *annually* sacrificed, the victims of dirt disease. If a colliery or a railway in such a town destroyed that number at one fell stroke once every year, Parliament and the nation would be up in arms to put a stop to such wholesale slaughter.

But, although science proves to us conclusively that such sacrifices are more or less constantly being made in our cities, towns, and villages, yet, despite all remonstrances, a number of our sanitary councils stand by and tolerate such a state of things; and, however valuable may be the life of the victim of insanitary conditions, neither he nor his friends can obtain any compensation for the disablement or destruction of that life.

Actuated thus by a sense of the importance of the work to be carried out, I should proceed to lay down my system of sewerage in the manner now to be described; and, that you may the more easily understand my explanations, I will assume an ideal district or building plot. The plot may be any shape you please, and it may be on flat ground or on undulated surfaces—it matters not what its shape or configuration may be. For the purpose of my explanation, however, I will ask you to assume that the plot to which I refer is low-lying, and without any defined declivity to a natural outfall. The contents of the plot are $43\frac{16}{100}$ acres. The houses are 240 in number, and they are cut up into 24 blocks, with 10 houses in each block. We will assume it to be a seaside resort, and that an average of 8 persons live in each house. This would give 1,920 as the population to provide sewers for. This population might be doubled readily without increasing the *first cost* of the sewerage works upon my system. In the centre of the plot would be placed what is called an "Ejector Station." There I should sink a manhole deep enough to enable me to fix a "Pneumatic Sewage Ejector," to receive the sewage discharges gravitating and converging from the north, south, east, and west to that point. The size of the gravitating sewer-pipes, leading the sewage from the backs of the houses to the "ejector station," is uniform, viz., 6 inches in diameter, and the gradient, say, 1 in 200. At the heads of the sewers leading to the "ejector station" a small "Shone's Hydraulic Syphon Ejector," for flushing [illegible] [illegible] [illegible] Figs. [illegible] 8, and 10), would be fixed. Small [illegible] [illegible] [illegible] [illegible] by which atmospheric air would [illegible] [illegible] [illegible] would also be inserted at intervals along the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] from the longest sewer-pipe,



measuring from its head to the discharging end at the ejector, being [illegible] [illegible] [illegible] and both ends being open, and the middle portions of the sewer being properly ventilated, and the sewer itself adjusted in its size and inclination to suit, as near as may be, the small intermittent discharges of the sewage, dangerous sewer air could not accumulate under such conditions.

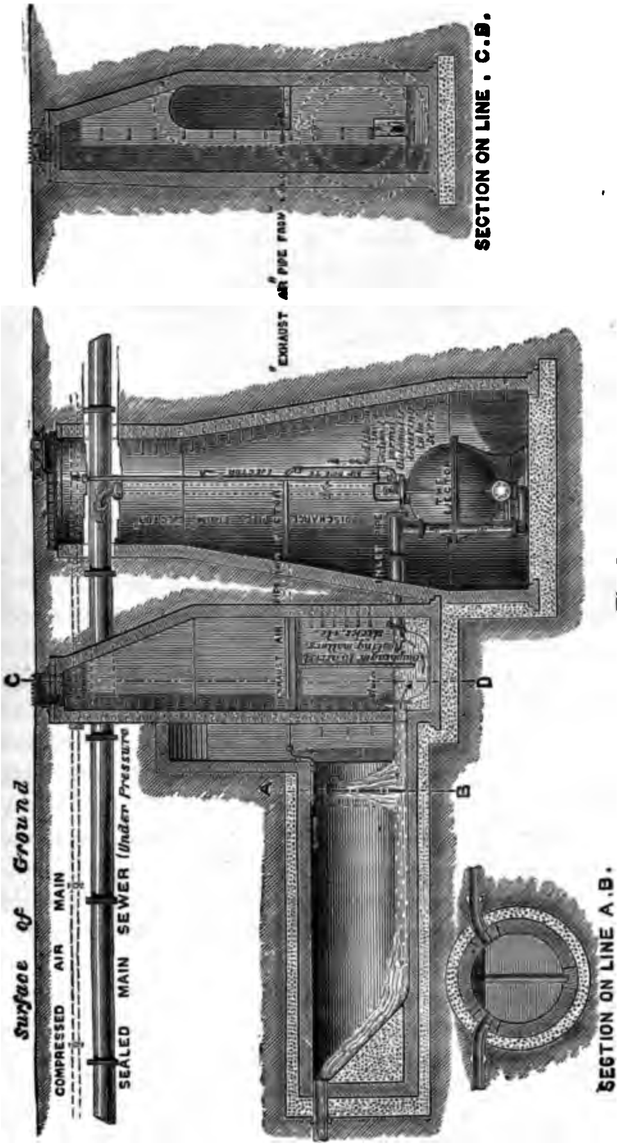


Fig. 2.

Again, taking the sewer as being 6 feet deep at its head, it would be 12 feet deep at the discharging point in the reservoir of [illegible] ejector [illegible] as our reservoir* is 5 feet deep, and [illegible] to discharge into an ejector (see Fig. 2) similar to the V[illegible] the bottom of the ejector chamber would then be [illegible] feet deep. Forms of ejector stations are shown in Figs. [illegible]

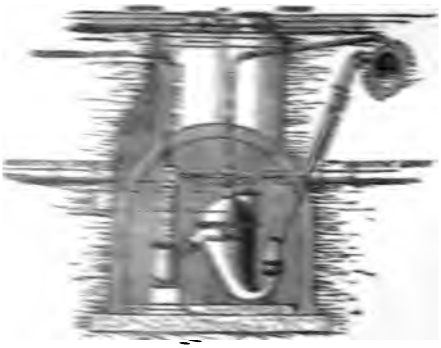


Fig. 2.

The [illegible] V[illegible] (Fig. 2) is spherical in shape, 5 feet in diameter, and made of cast-iron. It holds down to the discharging line [illegible] gallons. If a similar ejector were used for our ideal [illegible] number of discharges it would make daily, from the [illegible] assuming 31 gallons of sewage per head per [illegible] discharges in the 24 hours; but as, [illegible] assuming half the daily quantity of sewage [illegible] away from the population in 400 minutes, then the [illegible] time of each discharge would be ($\frac{400}{[illegible]}$ =) 4·5 minutes [illegible] during the period of maximum flow of sewage the ejector would be filled and emptied every 4½ minutes, but during the remaining [illegible] minutes of the day the ejector would take on the average ([illegible] =) 11·68 minutes to fill and empty.

We will assume that this ideal plot, which we have been considering, is 1 out of 20, and that in each of the 20 plots there is an ejector discharging, say, into an 18-inch iron main, which is common to the whole; that the outfall is a mile away in the sea, and that the lift from the discharging line, in the ejector, to the centre of the sewage main under the street, is 20 feet; that the ejector is on a level with the outlet end of the same pipe, which is fixed in the sea at low-water mark; and that this outlet end is 15 feet below ordinary high-water mark.

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* The reservoir would probably be dispensed with in general practice.

Adopting my "Sewerage Table"* as our guide to determine the head necessary to overcome friction in a mile of sewer 18 inches in diameter, and reckoning upon a velocity of about 3 feet per second, we shall find that a water head of 15·1 feet, or a pressure of 6·553 lbs. per square inch, will be needed. This would be equal to a gradient of 1 in 350, but, as our out-fall does not admit of any gradient at all, gravitation power will not avail us (see Fig. 3). At low-water mark we should require pneumatic pressure to overcome friction only, as already stated, of 15·1 feet.

Height of tide, ... 15·0 „

Total, ... 30·1 „

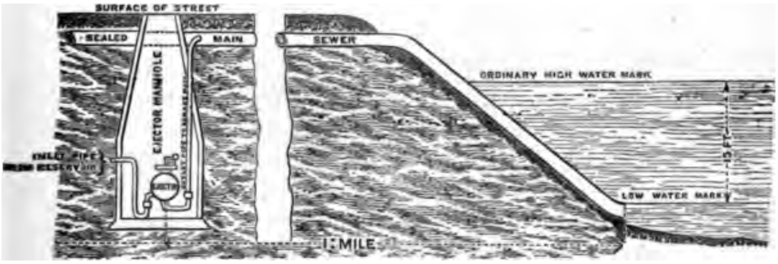

Fig. 3.

We thus find that the forcing power required at the ejector would alternate between 15·1 feet as a minimum, and 30·1 feet head of water as a maximum, and as a pressure of ·434 lb. on the square inch will balance a column of water 1 foot high, then 15·1 × ·434 = 6·553 lbs. for the minimum, and 30·1 × ·434 = 13·06 lbs. for the maximum, pressure per square inch, to force the sewage into the sea at a constant velocity, irrespective of the ebb and flow fluctuations of the tide. If we produce a volume of air at the pressure needed to correspond to the volume of sewage to be ejected, it will be as effectual in displacing the sewage from the ejector—which may be regarded as a substitute for, or the equivalent of, a pump—as if it were a solid metal plunger; and this is the power which I propose to utilise by way of overcoming the difficulties inherent to the gravitating system of sewerage *per se.*

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* Published by E. & F. N. Spon, London, price 2s. 6d.

In sewerage works we cannot catch the sewage and pond it, and let it off, as from a water-works reservoir, but upon my system we can collect it at certain stations underground and pass it into an ejector, from whence it can be ejected by pneumatic pressures equivalent to the water heads spoken of in hydraulics. I will now explain the action of the ejector.

Fig. 4 shows the ejector in the act of discharging the sewage into an iron sewage-main, resembling an ordinary street water-main, the which would convey the sewage, it may be, to an existing gravitating sewer, or to a farm, or garden lands suitable for irrigation, or to sea out-falls. The ejector would discharge its contents (regularly, as it got filled with fresh sewage) up the discharge or outlet pipe into the sewage main, whence it would travel—*unobserved, and without giving off offensive smells*—to its destination; and, supposing the out-fall to be the sea, the ejector would force the sewage into the sea at all stages of the tide, as already explained. In the figure, the arrows at the top, immediately below the automatic gear, indicate the direction whence the compressed air rushes into the ejector. The valve 1, at the bottom of the sewage inlet pipe, is on its seat, preventing

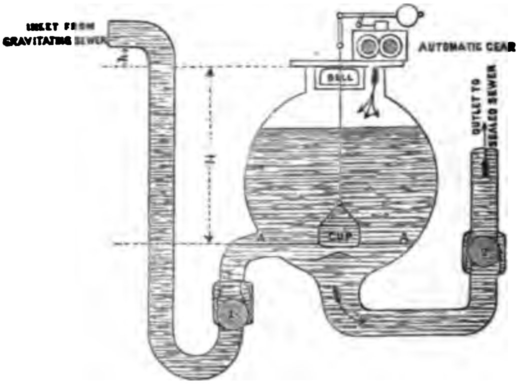


Fig. 4.

the sewage escaping back into the sewer or reservoir, and the valve 2, at the bottom of the outlet sewage-pipe, is off its seat, permitting the sewage to pass into the sealed iron sewage-main, or gravitating sewer, above, as the case may be. Directly the sewage has passed out of the ejector, down to the level of the line AA, the "cup" pulls the spindle of the automatic apparatus down to the position shown by Fig. 5, and instantly the compressed air feed-valve is closed, and, immediately afterwards, the air outlet-valve is opened to allow the compressed air contained within the ejector (which had ejected the sewage) to escape, it may be, into the manhole containing the ejector, or into the reservoir, or gravitating sewer, or elsewhere.

Fig. 5 shows the ejector in process of filling. The ball-valve 1, in the sewage inlet-pipe, in this case is *off* its seat, permitting the sewage to pass into the ejector; the ball-valve 2, in the sewage outlet-pipe, is *on* its seat, preventing the sewage from returning back into the ejector. Meanwhile the volume of sewage passing into the ejector causes a corresponding volume of air, at atmospheric pressure, to pass away from the ejector, through the outlet-valve and exhaust-pipe, into the manhole or elsewhere. The ejector would thus have fresh sewage passing out of it and fresh compressed air passing into it, *firstly;* and fresh sewage passing into it, and fresh air passing out of it, *secondly;* and the whole process requiring no attendant, the action being perfectly automatic.

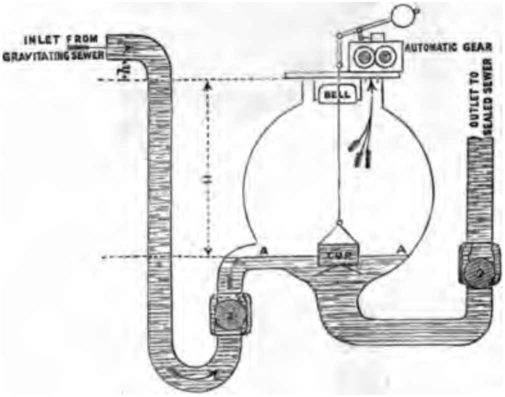


Fig. 5.

Figs. 6 and 7 illustrate an apparatus which I propose to call "Shone's Hydraulic Syphon-Ejector," by which the slops and waste liquids of a house may be made to automatically flush the house-sewer or drain. The apparatus consists of a tank for the reception

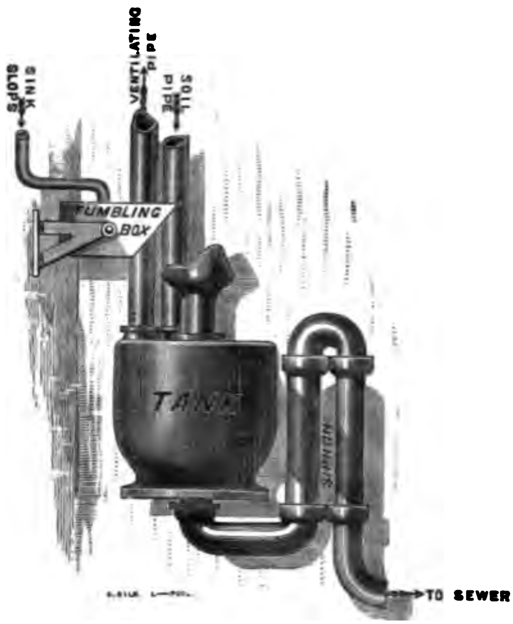


Fig. 6.

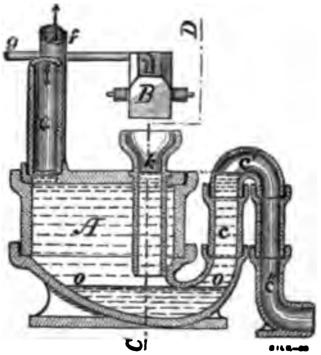


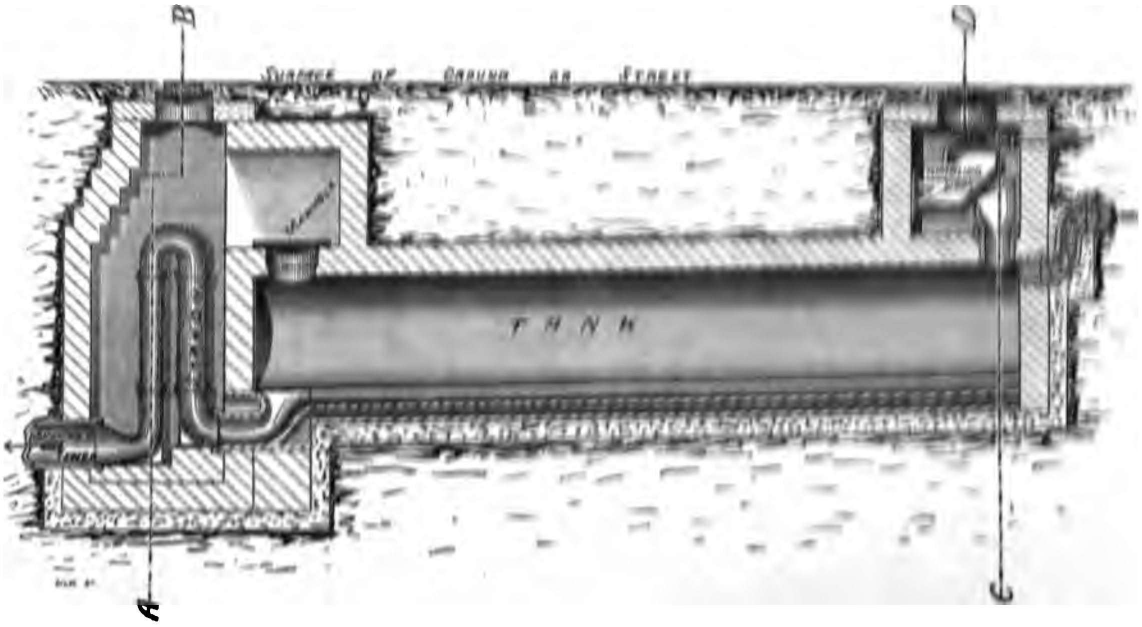
Fig. 7.

of *all* domestic waste liquids. The discharges from the water-closet may pass direct through the soil-pipe into the upper part of the tank, as shown, or the soil-pipe may enter at any other part of the tank. From the bottom of the tank a pipe is led, which is bent upwards into a syphon, the long leg being connected with the house-drain or sewer; a funnel pipe is inserted in the top, the lower end reaching nearly to the bottom of the tank; the scullery and kitchen slops are conducted by a pipe into a tumbling-box, fixed so as to discharge its contents, when full, into the funnel-pipe. Ventilating pipes would be provided, so as to break the connection—as far as sewer air is concerned—between the sewer and the flush tank on the one hand, and the house and the flush tank on the other.

The tank being filled with house sewage, through the soil-pipe, etc., the kitchen and scullery slops would continue to flow into the tumbling box, and when the latter was filled it would suddenly cant over, and discharge its contents into the funnel pipe (entering the tank). The effect of this action would be to start the syphon into operation by filling its upper bend. The syphon would continue its action until the tank was emptied, when the entrance of air into the short leg would stop its working. The flush tank would act also as a perfect trap, between the house and the drain or sewer. At every discharge of a W.C., or of the tumbling-box, a quantity of air would be displaced from the tank, and find its way up the main ventilating pipe leading to the roof of the house, and the current of air thus caused would induce a current of air in the right direction, in the branch ventilating pipes connected with the house-sewer, thereby insuring healthy and efficient ventilation of the tank, and all its pipe connections.

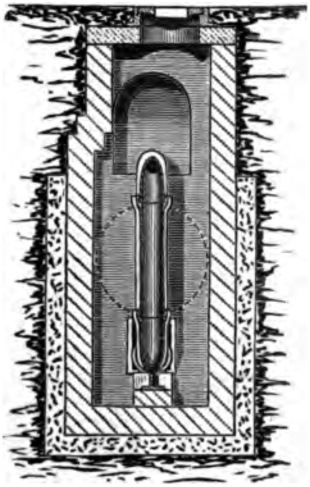
The Syphon-Ejector can be used to receive the scullery slops only, for the purpose of flushing; the discharge from the W.C.'s going direct into the house drain, or sewer; or it may be used at the head of a street sewer, and the tumbling-box fed by a small supply pipe, regulated by a tap according to requirements, from the water-works main. By this means the street sewer would be regularly and automatically flushed. The flush tank may also be used in connection with a street-gulley, the street water flowing into a chamber for the retention of the road detritus, etc., and passing from thence into the flush tank, it would be discharged into the drainage or sewer-pipe. See Figs. 8, 9, and 10.

The adoption of the Hydraulic Syphon-Ejector in connection



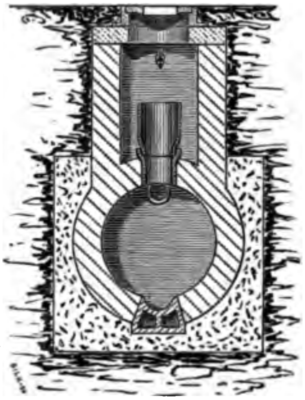
LONGITUDINAL SECTION.

FIG. 2



CROSS SECTION ON LINE A B.

Fig. 9.



CROSS SECTION ON LINE C D.

Fig. 10.

with house drainage would confer advantages that cannot be overestimated, inasmuch as it would use the sewage-proper of the house as a means of cleansing and keeping clean the pipe leading to the street sewer (see Fig. 11). Without some such means the house sewage, with all the organic solids contained therein, passes almost constantly down the branch sewer, in an attenuated stream, and, decomposing, gives off those noxious sewer gases which are so dangerous to health. These deposited solids, in some cases, temporarily accumulate so as to block up the sewer, until the head of liquid behind is of sufficient height to force a passage through; in other cases the solids accumulate to such an extent as to permanently block the sewer, and render it utterly useless and highly dangerous. But by means of the "Syphon-Ejector" the house-sewage would be discharged into the branch sewer in compact volumes, and the sewage, with its solid ingredients, would thereby flow rapidly away, and effectually prevent any accumulation of solid matter in the pipe. The Tank is so constructed that all its contents are cleared out with each discharge, without allowing any sediment to remain. It is thus self-cleansing in itself, as well as a means of cleansing the sewer or drain.

The Syphon-Ejectors can be made of different sizes and shapes,

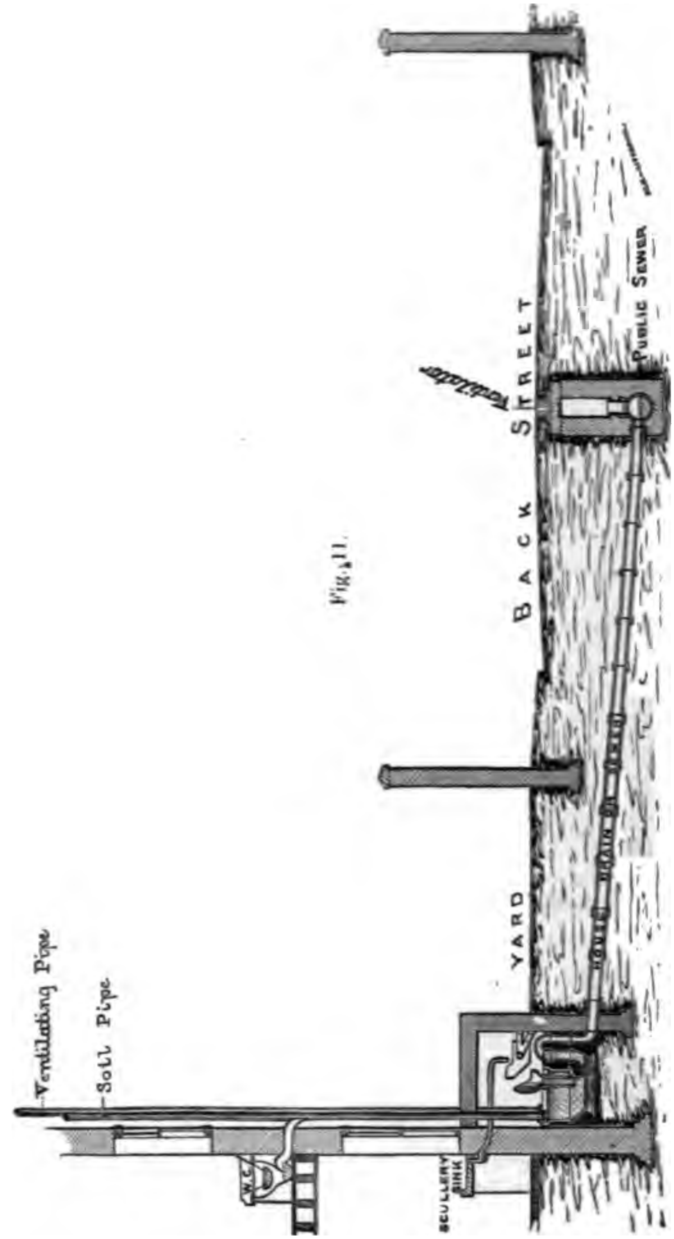


Fig. 11.

Ventilating Pipe
Soil Pipe
W.C.
SCULLERY SINK
YARD
BACK STREET
Ventilator
PUBLIC SEWER
HOUSE DRAIN

to suit various conditions and circumstances. As already stated, they are also intended to be fixed at the heads of the small, properly-graded, tributary drains, leading the sewage from the houses to the ejectors.

Now, I feel persuaded in my own mind that your President, Dr. Fergus, and Vice-President, Dr. Wallace, as well as your Officer of Health, Dr. J. B. Russell, will agree with me, when I express the opinion that the application of air to the expulsion of sewage will be beneficial rather than otherwise. Dr. Fergus made the following remark, amongst others, in his evidence before Sir John Hawkshaw, the commissioner appointed to inquire as to the purification of the River Clyde:—"There is no doubt that running water has considerable power to destroy excremental matter, but it is the air contained in the water that has that effect." Dr. J. B. Russell, in his first lecture on "The Theory and Prevention of Infectious Diseases,"* said, "The destructive processes to which those cast-off matters are subjected are all processes of oxidation, and are all, directly or indirectly, effected by atmospheric air. They partake, therefore, of the nature of combustion . . . The decomposing activity both of soil and water depends upon the air which they contain." "We are told by the Rivers Pollution Commission that 'the oxidation of the organic matter in water is effected chiefly, if not exclusively, by the atmospheric oxygen dissolved in the water—such dissolved oxygen being well known to be, chemically, much more active than the gaseous oxygen of the air.'" ("Domestic Water Supply," p. 137.) "It must be explained, however, that, although in equal volumes, the oxygen in water may be, chemically, more active than the oxygen of the air, as we find it in operation around us, from the more frequent renewal and the greater quantity thus brought into action, air is much the most destructive agent, and soil and water are destructive in proportion to the air which they contain."

If, then, we can keep the sewage from decomposing in and at the houses yielding it, and if we can prevent it from decomposing on its way to and when in the ejector, all the while it will be in contact, of course, with atmospheric air, and in that condition it would be harmless. When the Ejector got filled, atmospheric air (three or four volumes condensed into one) would still be in contact with the undecomposed sewage. The act of expulsion might take a minute, more or less according to the size of the ejector and the pressure of the air employed to eject it. Under such a system of collection and ejection, I confess I do not see how the hygienics of the system can be otherwise than satisfactory. With proper scavenging, and cleansing of streets, &c., the rain and subsoil water of a town, drained of its sewage in the manner described, could be allowed to pass into our brooks, rivers, or seas, with impunity.

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* Delivered and published under the auspices of the Lord Provost, Magistrates, and Council of the City of Glasgow.

It must be admitted, I think, that compressed air is peculiarly well adapted as a motor for the propulsion of sewage. We might adduce several reasons in support of this assertion. We will content ourselves by stating the following in the meantime:—

(1) It is, as we have just seen, one of Nature's agents for the purification of waste organic matters.

(2) It is an agent of which we have an unlimited supply in the atmosphere around us.

(3) It is a motor that, once it is produced, can be conveyed and divided amongst any number of stations near to or far apart from each other, without any significant or appreciable loss. The following comparison of the friction of water and air under similar conditions, as to the diameter and length of pipe and velocity of current, will give you an idea of the smallness of the loss occasioned by passing air, at even comparatively high velocities, through pipes:—

Given, a pipe 1 mile long and 12 inches diameter, the head required to pass—

(*a*) Water, at a velocity of 4 ft. per second, would be 40·4 ft. of water.
(*b*) ,, ... 9 ft. .. .. 204·6 ft. ,,
(*c*) Air .. .. 4 ft. .. .. 0·03 ft. ,,
(*d*) ,, ... 9 ft. .. .. 0·15 ft. ,,

This comparison shows that, as compared with water, the friction of air is as 1 to 1336 about!

The heads stated above are calculated from Box's formula, as given in his work on "Hydraulics," for cases (*a*) and (*b*), and from formula given in his treatise on "Heat" for cases (*c*) and (*d*).

The practical truth of the above statement as to the insignificant loss by friction in the flow of air through pipes has been abundantly proved by experience in collieries, and also in the Mont Cenis Tunnel boring operations.*

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* See Simm's "Practical Tunnelling." Third edition.

(4) It is a motor, as compared with steam, that is unobjectionable on account of the absence of heat radiating from the pipes conveying it, as the temperature of the air conveyed is always the same as, or very nearly, that of the outside atmosphere.

(5) Where water power is obtainable within a reasonable distance from a town (and there are a great number of such places) proposed to be sewered upon my system, the compressors could be worked by turbines. This would do away with the charge for fuel altogether, and turbine power thus utilized could be transmitted to long distances, and made to operate in many places where ordinary pumping could not be adopted without the use of steam power; and the compressors used in connection with any scheme designed in accordance with my sewerage system may be fixed at one place to supply the air through pipes leading to the several ejector stations; or, if found more convenient, the compressors may be separated, and made to discharge the compressed air at two or more points of the system of air-mains. In the latter case, the motor for compressing the air may be either steam or water, or these may be combined—*i.e.*, steam power compressing air at one place, and water through turbine power compressing air at another place.

I am aware that compressed air is looked upon by engineers as an expensive motor to produce and utilize, and no doubt there have been sufficient reasons, in the imperfections of air-compressing machinery and in the losses arising from the application of the air to the driving of machines, to impress engineers with its expense. But as air-compression is better understood so will the machines for its production become more perfect in design and economy of working; and rapid strides have been made of late years in the development of air-compressors. To my mind the Sturgeon "High Speed," which I have been using in my trials at Wrexham, and which was manufactured by Messrs. Clayton, Howlett, & Co., London, and the Sturgeon "Trunk" Compressor, manufactured by Messrs. Thwaites Brothers, Bradford—an illustration of which is given at Fig. 12—appear, especially the latter, theoretically to be well designed for the economical compression of air.

Again, in the raising of liquids upon my system the ejectors are not to be regarded as pumps in which the motor has to overcome the friction of glands, plungers, and all moving parts necessary to their working, because in the ejector the air has nothing more to

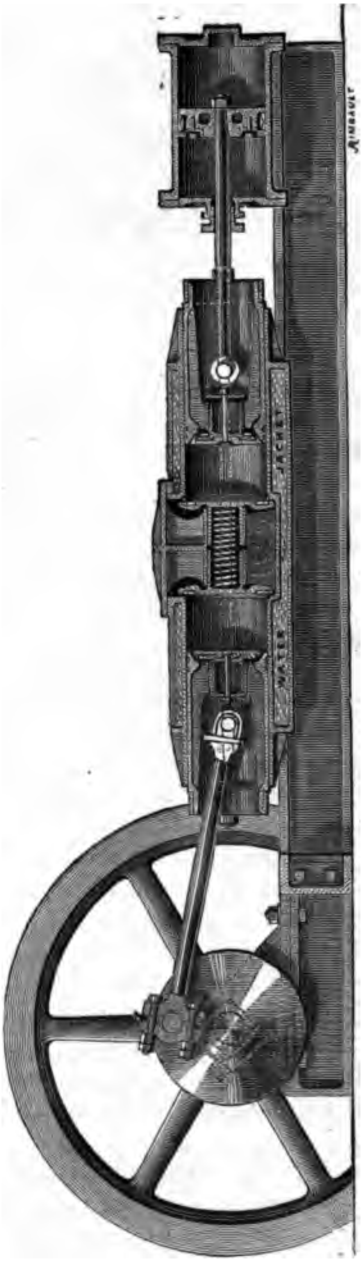


Fig. 12.

do than to force out directly, without the intervention of any piston or plunger, the liquid contained therein; and, after allowing for *all* losses in the compression of air, I am satisfied, after careful investigation of various recorded results, that the cost of raising sewage and other liquids upon my system will compare very favourably with those of the best class of ordinary pumping engines. It would lengthen this paper too much if I were to give examples of the power required to work any given sewerage scheme upon my system, but I may say that I propose to go minutely into the question of cost in a work that will shortly be published, treating of pneumatic sewerage.

I may, however, state here that by using some such steam generator as Messrs. Thwaites, Stuart, and Sturgeons' (of Bradford) Patent "Central Feed Vertical Boiler," which is intended to use up the solid waste refuse of towns, in the shape of ashes, &c., steam may be produced at little or no cost. In this way the solid wastes could be subjected to "cremation," and in the process steam could be generated, to compress air, to eject the liquid wastes of our towns away therefrom, as rapidly, practically, as they are discharged into the sewers.

I might also add that my pneumatic system is applicable to mansions, hospitals, asylums, military depots, hotels, offices, workshops, prisons, schools, mills, factories, and such like buildings, each of which could be provided with its own distinct ejector, into which the sewage and drainage of the place could be made to gravitate rapidly when fresh, so that it may be forced therefrom into the existing sewerage system of the town or district, and thereby prevent the generation of sewage gas within such buildings and their premises, and at the same time cut off all communication for the flow of poisonous sewer gases from the main sewer.

Fig. 13 is intended to show (1) how a mansion having its drainage now in direct communication with a public sewage-gas-producing sewer may be disconnected therefrom by the interposition of a pneumatic ejector; and (2) how the drainage of the same mansion could be still further improved, by placing the ejector a little deeper in the ground, as shown by the dotted lines, for the all-important sanitary purpose of giving to the small drainage pipes steeper gradients to make them "self-cleansing," whilst they discharge the sewage fresh as it is produced, as all sewer-pipes should do. The ejector, being automatic and worked by fresh atmospheric air, would discharge the sewage noiselessly and innocuously into the public sewer,

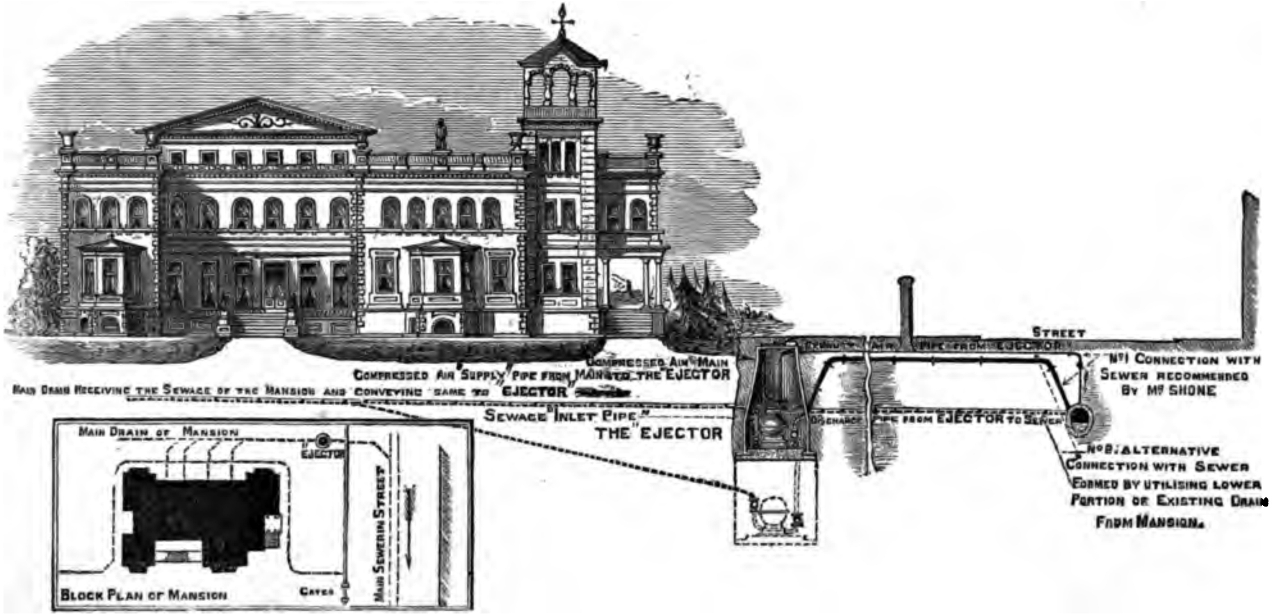

Street
Exhaust Air Pipe from Ejector
No. 1 Connection with Sewer recommended by Mr. Shone
Compressed Air Main
Compressed Air "Supply" Pipe from Main to the "Ejector"
Main Drain receiving the Sewage of the Mansion and conveying same to "Ejector"
Sewage "Inlet Pipe"
The "Ejector"
Discharge Pipe from Ejector to Sewer
No. 2. Alternative Connection with Sewer formed by utilising lower portion of existing Drain from Mansion.
Main Drain of Mansion
Ejector
Main Sewer in Street
Gates
Block Plan of Mansion

Fig. 13.

and at the same time render the mansion premises free from the insidious and dangerous gases generated in the public sewer.

Mansions, &c.—already drained of their sewage by means of flatly-laid sewers, which are absolutely unsuitable on that account to create a certain and reliable scour of the drains leading into cesspools or public sewers—could secure perfect flushing by using the Syphon-Ejector, and placing the bottom of it about one foot, more or less, above the head of the sewer drain, terminating at the mansion (see Figs. 13 and 14). This would in some cases (see Fig. 13) supersede the necessity of fixing a "Pneumatic Ejector" to do the work as per illustration (Fig. 13).

XXIII.—*Contributions to the Technology of Sulphuric Acid.—On the Distribution and Condensation of the Gases in the Leaden Chamber.* By JAMES MACTEAR, F.C.S., F.I.C., President of the Section.

[Read before the Chemical Section, April 7th, 1879.]

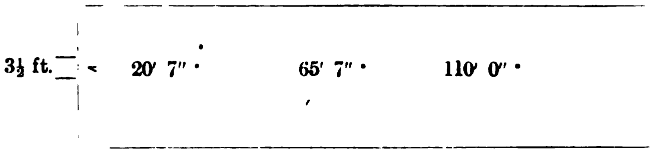
A SMALL book on the chemistry of the sulphuric acid manufacture was published in 1873, by the late Mr. H. A. Smith. It contained the results of much hard work, and gave many interesting figures. The results of a series of laboratory experiments led him to believe that the greatest amount of condensation of the sulphuric acid took place at the bottom of the chamber, and that its upper portion was of use principally as a reservoir for the gases. He therefore reasoned that the best form of chamber for the production of sulphuric acid would be one where the height was small in proportion to the length.

He attempted to prove his theory by an examination of the working of a chamber actually in use, and of considerable size, its dimensions being—

140	feet	long,
30	,,	high,
25	,,	wide,

containing 105,000 cube feet of space, and capable of using about 50 cwts. of sulphur, in form of pyrites, per 24 hours.

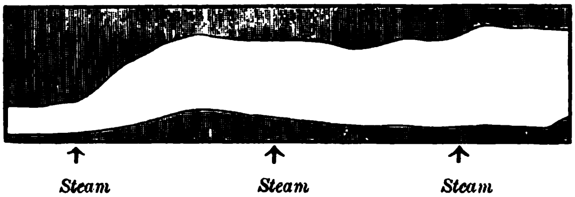
Steam was injected at three points in the side of this chamber, as shown in plan below, and also along with the sulphurous gases entering the chamber, which they did through a pipe 3½ feet in diameter.



He drew out of the chamber a series of samples of the gases, at points 10 feet apart from one end of the chamber to the other, and at two levels, 15 feet and 3 feet above the bottom respectively—there being thus 14 different samples at each level. The gases thus obtained were then tested for sulphurous, sulphuric, and nitric acids, and I have embodied his results in the following diagrams :—

SULPHUROUS ACID.

Diagram No. 1—Sulphurous Acid.

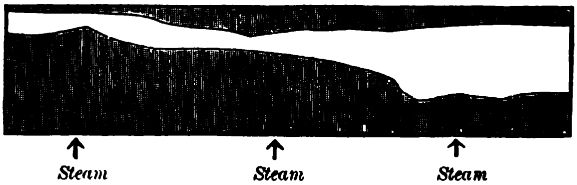


The shaded portion of the diagram shows the amount of sulphurous acid existing as such at the various points of the chamber where the samples were drawn—the upper shaded portion representing the amounts found at or along the line at 15 feet from floor of chamber, the lower shaded portion those found along the line at 3 feet from floor.

The effect of the introduction of the steam is well marked in the diagram by the fall in the amount of sulphurous acid found at or close to the points at which it is injected—viz., at 20 feet, 65 feet, and 110 feet from entrance of gases.

SULPHURIC ACID.

Diagram No. 2—Sulphuric Acid.

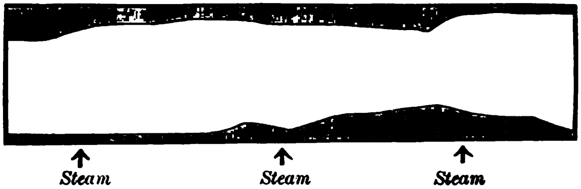


This diagram, when closely examined, shows some most extraordinary results, there being little or no sulphuric acid found at

15 feet above floor of chamber for some distance from entrance of the gases, while at the 3 feet level the amount is as much as 81 per cent. There is little doubt that the injection of the steam with the gases into the chamber, through a pipe of 3½ feet diameter, at a height between 15 feet and 24 feet from floor, would cause a strong current of gas, chiefly SO_2, inward and upward, whilst a back current would carry the partially-converted gases towards the bottom and end of the chamber, where, of course, the largest amount of SO_3 would naturally be found, as, no matter at what height any molecule of sulphuric acid was formed, it must pass through the lower zone of the chamber ere reaching the liquid acid upon the bottom.

NITRIC ACID.

Diagram No. 3—Nitric Acid.



Regarding the amount of nitric acid (which I take to mean all the nitrous compounds calculated to nitric acid), Mr. Smith says:—"The variations in the percentage of nitric acid are not very great, being only between 3 per cent. and 26 per cent., these being the maximum and minimum amounts. It attains its greatest height at 100 feet and 110 feet from end of the chamber, and then sinks rapidly down to 3 per cent. at 140 feet."

If we now examine carefully the figures represented in the diagrams, I think it will be obvious that Mr. Smith's conclusions were drawn from totally insufficient data to enable him to decide as to the distribution and action of the gases in the chamber.

Tabulating his results at the two levels of 15 feet and 3 feet from floor of chamber, for sulphurous, sulphuric, and nitric acids, we have the following figures:—

	DISTANCE IN FEET FROM ENTRANCE OF GASES.														
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	
SO_2, -	72	71	46	32	25	26	30	22	29·5	22	23	13	18	18	At 15 feet.
SO_3, -	0	0	6	18	23	20	18	16	19	12	12	7	7	10	
N_2O_5,	25	18	13	13	8	7	14	13·5	16	20	7	3	6	6	
TOTALS,	97	89	65	63	56	53	62	51·5	64·5	54	42	23	31	34	

	DISTANCE IN FEET FROM ENTRANCE OF GASES.														
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	
SO_2 -	3	8	16	29	28	18	19	20	17	17	14	13	8	16	At 3 feet.
SO_3 -	81	89	76	70	68	67	60	56	48	30	38	30	36	33	
N_2O_5 -	8	3	6	4	4	12	8	17	20	26	26	15	12	3	
TOTALS,	92	100	98	103	100	97	87	93	85	73	78	58	56	52	

On glancing at the totals in above Table it can at once be seen that the expression "percentage," as regards the various acids, requires some explanation. It is by no means clear what is meant by it, as it cannot mean percentage in the chamber gases, and certainly is not the percentage of the total acids, as one of the totals mounts up to 103 per cent., while one is as low as 23 per cent. These irregularities are quite to be looked for if the estimations of the three acids were not made in the same sample of gas, and I am inclined to believe that separate samples were used for each estimation. Owing to the constant whirling about of the gases in the chamber, caused chiefly by the mechanical force of the steam jets, it would be highly improbable that two samples, even taken at very short intervals of time, would have the same composition; and such irregular results—as these are seen to be from comparing the figures—are utterly misleading as to the composition of the gases.

The variation is very marked indeed in the case of the nitric acid, which under normal conditions must go on increasing in amount, as the SO_2 gets converted into SO_3 and is removed by condensation, but which the figures as above treated shew to be very much less at the exit than at the entrance of the chamber, almost before any condensation has taken place.

Vitriol makers are familiar with what is usually called the "going through" of a series of chambers. By this technical expression is meant that condition of the chambers where there has been, by some means or other, a scarcity of nitrous compounds for a short time, and where, as it were, a block of the gases pass through the whole series of the chambers, pale in colour, and with much of the SO_2 unconverted.

As the potting of the nitrate of soda is always more or less irregular even at best, this "going through" is in a lesser degree continually taking place, and the gases must therefore show great irregularity from this cause alone.

The reasoning based on such figures as I have quoted—as to the best form of chamber for the manufacture of sulphuric acid—could not be other than fallacious, and I trust to show that it is not only so, but completely at variance with the actual facts of the case.

That the matter may be more clearly put before you, we will assume that we are considering the case of a series of sulphuric acid chambers, six in number; that pyrites is used as the source of the sulphurous acid, and that the gases are led first through a Glover tower (or denitrator), then into No. 1 chamber, from which they pass into Nos. 2, 3, 4, 5, and 6 in turn, passing finally through a Gay-Lussac tower (or absorber), for the recovery of the nitrous compounds, which, it is well known, before the introduction of this apparatus, were all lost by escaping into the atmosphere. We will also assume that, in such a case as we are considering, the nitrous compounds present are equal to 10 per cent. of $NaNO_3$ on the sulphur burned, are calculated as N_2O_4, and are supposed to be altogether obtained from the Gay-Lussac acid denitrated in the Glover tower, while the residual gases escape with 10·4* per cent. of oxygen, ·33 grains per cubic foot nitrous compounds calculated as $NaNO_3$, and ·5 per cent. of the original sulphur escaping as SO_2; also that the gases are calculated as litres of gas per 100 grams sulphur.

The watery vapour present is omitted in the calculation, as it is most difficult to decide on the bulk it occupies in the chambers, and it may quite well for our purpose be neglected forthe present, as may also the absorption of nitrous compounds by the acid formed, or their reduction to lower oxides, or even to nitrogen.

To make more distinct the work done in each chamber, I have tabulated side by side the gases entering, and those leaving, each chamber, so that the alteration in their composition can be seen at a glance.

As the gases enter the Glover tower they contain 6·325 vol. per cent. of SO_2, which becomes at the entrance to the first chamber a fraction less owing to the addition of the N_2O_4 to the volume of the total gases.

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* This figure is taken for convenience of calculation. The amount of oxygen in escaping gases varies much in different cases. With tight chambers and good working it may be kept steadily about 7 per cent. to 7·5 per cent., but as chambers get old and leaky it often mounts to 10 per cent. or 11 per cent., this amount being found in the exit gases after passing all condensing towers, &c.

GLOVER TOWER.

	Gases Entering.			Gases Leaving.		
	Total Litres.	Centesimally.	Per 100 of SO_2.	Total Litres.	Centesimally.	Per 100 of SO_2.
SO_2,	69·754	6·325	100·000	69·754	6·318	100·000
O required to convert SO_2 into SO_3,	34·790	3·155	49·875	34·790	3·151	49·875
N equivalent to O fixed in Fe_2O_3 and SO_3,	499·109	45·620	715·527	499·109	45·206	715·527
O equal to air in excess,	103·815	9·414	148·831	103·815	9·403	148·831
N " " "	395·294	35·486	566·697	395·294	35·803	566·697
N_2O_4,	...	...	...	1·315	·119	1·855
Total,	1,102·762	100·000	1,480·930	1,104·077	100·000	1,482·815

The gases, after passing through the Glover Tower, pass into the first chamber, containing 6·318 vol. per cent. of SO_2, and the N_2O_4 amounts to 1·885 vol. per cent. of the SO_2, or only ·119 vol. per cent. of the total gases.

FIRST CHAMBER.

	Gases Entering.			Gases Leaving.		
	Total Litres.	Centesimally.	Per 100 of SO_2.	Total Litres.	Centesimally.	Per 100 of SO_2.
SO_2,	69·754	6·318	100·000	47·782	4·461	100·000
O required to convert SO_2 into SO_3,	34·790	3·151	49·875	23·776	2·200	49·759
N equivalent to O fixed in Fe_2O_3 and SO_3,	499·109	45·206	715·527	499·109	46·598	1,044·554
O equal to air in excess,	103·815	9·403	148·831	103·815	9·693	217·268
N " " "	395·294	35·803	566·697	395·294	36·905	827·287
N_2O_4,	1·315	·119	1·885	1·315	·123	2·752
Total,	1,104·077	100·000	1,482·815	1,071·091	100·000	2,141·620

The gases entering the first chamber of the series with 6·318 vol. per cent. of SO_2, and leaving it with 4·461 vol. per cent., showing that 31·5 per cent. of the SO_2 entering the chamber has been converted into SO_3 and condensed.

SECOND CHAMBER.

	GASES ENTERING.			GASES LEAVING.		
	Total Litres.	Centesimally.	Per 100 of SO_2.	Total Litres.	Centesimally.	Per 100 of SO_2.
SO_2, ...	47·782	4·461	100·000	27·365	2·630	100·000
O required to convert SO_2 into SO_3, . .	23·776	2·220	49·759	13·542	1·302	49·486
N equivalent to O fixed in Fe_2O_3 and SO_3, .	499·109	46·598	1,044·554	499·109	47·971	1,823·896
O equal to air in excess, ...	103·815	9·693	217·268	103·815	9·978	379·372
N ,, ,, ,, ...	395·294	36·905	827·287	395·294	37·993	1,444·524
N_2O_4, ...	1·315	·123	2·752	1·315	·126	4·805
Total, . .	1,071·091	100·000	2,141·620	1,040·440	100·000	3,702·083

The gases entering the second chamber of the series with 4·461 vol. per cent. of SO_2, leave it containing 2·630 vol. per cent., showing that of 100 parts SO_2 entering the chamber 42·72 parts have been converted into SO_3 and condensed.

THIRD CHAMBER.

	GASES ENTERING.			GASES LEAVING.		
	Total Litres.	Centesimally.	Per 100 of SO_2.	Total Litres.	Centesimally.	Per 100 of SO_2.
SO_3, ...	27·365	2·630	100·000	14·314	1·402	100·000
O required to convert SO_2 into SO_3, . .	13·542	1·302	49·486	7·000	·686	48·903
N equivalent to O fixed in Fe_2O_3 and SO_3, .	499·109	47·971	1,823·896	499·109	48·892	3,486·859
O equal to air in excess, ...	103·815	9·978	379·372	103·815	10·169	725·269
N ,, ,, ,, ...	395·294	37·993	1,444·524	395·294	38·722	2,761·590
N_2O_4, ...	1·315	·126	4·805	1·315	·129	9·817
Total, . .	1,040·44	100·000	3,702·083	1,020·847	100·000	7,031·808

The gases entering the third chamber of the series with 2·630 vol. per cent. of SO_2, leave it containing 1·402 vol. per cent., showing that of 100 parts of SO_2 entering the chamber 47·5 parts have been converted into SO_3 and condensed.

FOURTH CHAMBER.

	Gases Entering.			Gases Leaving.		
	Total Litres.	Centesimally.	Per 100 of SO_2.	Total Litres.	Centesimally.	Per 100 of SO_2.
SO_2, ...	14·314	1·402	100·000	7·115	·704	100·000
O required to convert SO_2 into SO_3, . .	7·000	·686	48·903	3·392	·336	47·674
N equivalent to O fixed in Fe_2O_3 and SO_3, .	499·109	48·892	3,486·859	499·109	49·415	7,014·884
O equal to air in excess, ...	103·815	10·169	725·269	103·815	10·278	1,459·100
N " " "	395·294	38·722	2,761·590	395·294	39·137	5,555·784
N_2O_4, ...	1·315	·129	9·187	1·315	·130	18·482
Total, . . .	1,020·847	100·000	7,031·808	1,010·040	100·000	14,095·924

The gases entering the fourth chamber of the series with 1·402 vol. per cent. of SO_2, leave it with ·704 vol. per cent., showing that of 100 parts of SO_2 entering the chamber 50·25 parts have been converted into SO_3 and condensed.

FIFTH CHAMBER.

	Gases Entering.			Gases Leaving.		
	Total Litres.	Centesimally.	Per 100 of SO_2.	Total Litres.	Centesimally.	Per 100 of SO_2.
SO_2, ...	7·115	·704	100·000	2·616	·261	100·000
O required to convert SO_2 into SO_3, . .	3·392	·336	47·674	1·136	·113	43·425
N equivalent to O fixed in Fe_2O_3 and SO_3, .	499·109	49·415	7,014·884	499·109	49·748	19,079·090
O equal to air in excess, ...	103·815	10·278	1,459·100	103·815	10·347	3,968·463
N " " "	395·294	39·137	5,555·784	395·294	39·400	15,110·627
N_2O_4, ...	1·315	·130	18·482	1·315	·131	50·268
Total, . . .	1,010·040	100·000	14,095·924	1,003·285	100·000	38,251·873

The gases entering the fifth chamber of the series with ·704 vol. per cent. of SO_2, leave it with ·261 vol. per cent., showing that of 100 parts of SO_2 entering the chamber 63·3 parts have been converted into SO_3 and condensed.

SIXTH CHAMBER.

	Gases Entering.			Gases Leaving.		
	Total Litres.	Centesimally.	Per 100 of SO_2.	Total Litres.	Centesimally.	Per 100 of SO_2.
SO_2, ...	2·616	·261	100·000	·349	·035	100·000
O required to convert SO_2 into SO_3, . .	1·136	·113	43·425	...	...	...
N equivalent to O fixed in Fe_2O_3 and SO_3, .	499·109	49·748	19,079·090	499·109	49·917	143,011·175
O equal to air in excess, ...	103·815	10·347	3,968·463	103·815	10·382	29,740·418
N " " "	395·294	39·400	15,110·627	395·294	39·534	113,264·757
N_2O_4, " . "	1·315	·131	50·268	1·315	·132	376·791
Total, . .	1,003·285	100·000	38,251·873	999·882	100·000	286,399·141

The gases entering the sixth chamber of the series with ·261 vol. per cent. of SO_2, leave it with ·035 vol. per cent., showing that of 100 parts of SO_2 entering the chamber 86·6 parts have been converted and condensed.

GAY LUSSAC TOWER.

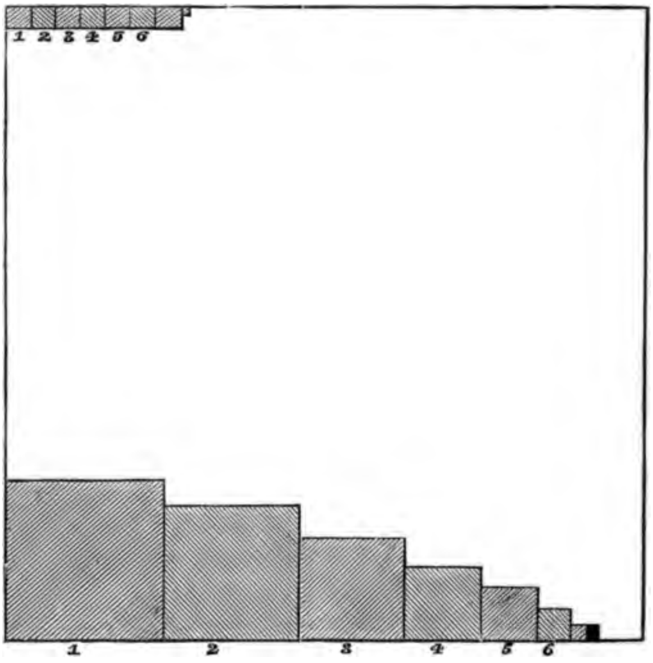
	Gases Entering.			Gases Leaving.		
	Total Litres.	Centesimally.	Per 100 of SO_2.	Total Litres.	Centesimally.	Per 100 of SO_2.
SO_2, ...	·349	·035	100·000	·349	·035	100·000
O required to convert SO_2 into SO_3, . .	...	...	...	...	...	...
N equivalent to O fixed in Fe_2O_3 and SO_3, .	499·109	49·917	143,011·175	499·109	49·978	143,011·175
O equal to air in excess, ...	103·815	10·382	29,740·418	103·815	10·395	29,740·418
N " " "	395·294	39·534	113,264·757	395·294	39·582	113,264·757
N_2O_4, " . "	1·315	·132	376·791	·099	·010	28·367
Total, . .	999·882	100·000	286,399·141	998·666	100·000	286,050·717

If we assume that no reduction, and therefore loss of nitrous compounds, has taken place (which, however, is not the case), then it would appear that 92·5 per cent. of the nitrous compounds have been arrested in the Gay Lussac Tower.

The relative bulks of the gases can perhaps best be shown by a diagram, in which the large square represents the chamber space, the lower squares the sulphurous acid in the successive chambers, and the upper squares the nitrous compounds, calculated as N_2O_4, the final small squares in both cases representing the amounts which escape into the atmosphere.

Diagram No. 4.

Relative Bulks of Chamber Gases.



Large square, total Chamber space.
Lower ,, SO_2 ,, ,,
Upper ,, N_2O_6 ,, ,,

In order to obtain the data for the calculation of the preceding Tables of the relative composition of the gases in the several chambers, a long series of determinations of the actual amounts of sulphuric acid condensed in the various chambers, which go to form a series, were made in the most careful way possible. In each case the amount of acid made in the course of a week was carefully measured and calculated out in the following manner:—

Comparative Chamber Condensation.

No. of Chambers.	Acid made.	H_2SO_4 in Acid made.	Excess Water.	Per cent. of H_2SO_4 made in the various Chambers.
	Tons.	Tons.	Tons.	
1,	23·52	19·89	3·63	32·20
2,	22·59	18·68	3·91	30·26
3,	20·35	14·89	5·46	24·11
4,	10·23	4·35	5·88	7·04
5,	5·84	3·09	2·75	5·00
6,	2·19	·86	1·33	1·39
Totals,	84·72	61·76	22·96	100·00

The average loss of acid calculated as H_2SO_4, on sulphur burnt, was estimated each day, and in this case amounted to

1·49 per cent.

I need not here describe the methods of estimating the escapes of sulphur and nitrogen acids, as I have on a former occasion had the pleasure of explaining them to the section.

It may be interesting to give here some further results on the relative amount of formation of acid in sulphuric acid chamber series of varying arrangement and size. The results are obtained by actual measurement, and extend over considerable periods of time, weekly averages being taken:—

(See Table next page.)

The series of chambers thus examined vary greatly in size and conditions of working. Some are hard pressed, and some are lightly worked.

All of them, with the exception of F, N, and O, are worked one into the other in sequence, and the chambers of each series are, as nearly as may be, identical in size one with another.

In case F the three chambers are of equal size, and the SO_2 is divided into Nos. 1 and 2, the residual gas from both then passing into No. 3.

COMPARATIVE CHAMBER CONDENSATION OF VARIOUS SERIES OF SULPHURIC ACID CHAMBERS.

No. of Chamber.	A in sequence.	B in sequence.	C in sequence.	D in sequence.	E in sequence.	F 1 and 2 into 3.	G in sequence.	H in sequence.	I in sequence.	K in sequence.	L in sequence.	M in sequence.	* N in sequence.	§ O 1 into 2} into 3 into 4} 5&6	P in sequence.	Q in sequence.
1....................	31·5	32·2	32·5	38·4	34·1	33·83	52·42	63·85	38·7	78·57	53·95	81·82	89·68	27·2	26·1	32·0
2....................	29·27	30·26	24·8	35·2	20·03	42·22	26·38	36·15	33·6	21·43	36·90	17·78	*5·15	15·9	31·3	29·0
3....................	18·71	24·11	19·3	15·6	19·66	22·61	16·53	...	12·9	...	9·15	...	*5·17	24·8	20·4	17·5
4....................	10·32	7·04	15·5	6·2	18·15	...	...	...	9·8	...	...	...	...	20·2	11·8	13·7
5....................	6·45	5·00	5·8	3·2	7·25	...	...	...	3·4	...	...	...	...	7·8	7·9	5·4
6....................	3·75	1·39	2·1	1·4	·54	...	...	...	1·6	...	...	...	...	4·1	2·4	2·4
7....................	...	...	...	...	·27	...	...	...	...	...	...	...	...	...	...	...
Tunnels, ...	...	...	...	...	...	1·34	4·67	...	...	...	...	·40	...	...	...	...
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99·9	100

In N* the chambers are irregular in size, Nos. 2 and 3 being together only about one-third the capacity of No. 1.

In O§ the chambers are all of the same size, and are worked in connection with two sets of kilns, the gas from one set passing into chamber No. 1, and thence into No. 2, the gas from the other set of kilns passing into chamber No. 3, thence into 4, and the residual gases from both No. 2 and 4 passing into No. 5, and then finally into No. 6.

We have now arrived at some idea of—

Firstly.—The relative amount of condensation which takes place in the various chambers of a series of vitriol chambers, and the proportion of H_2SO_4 made in each.

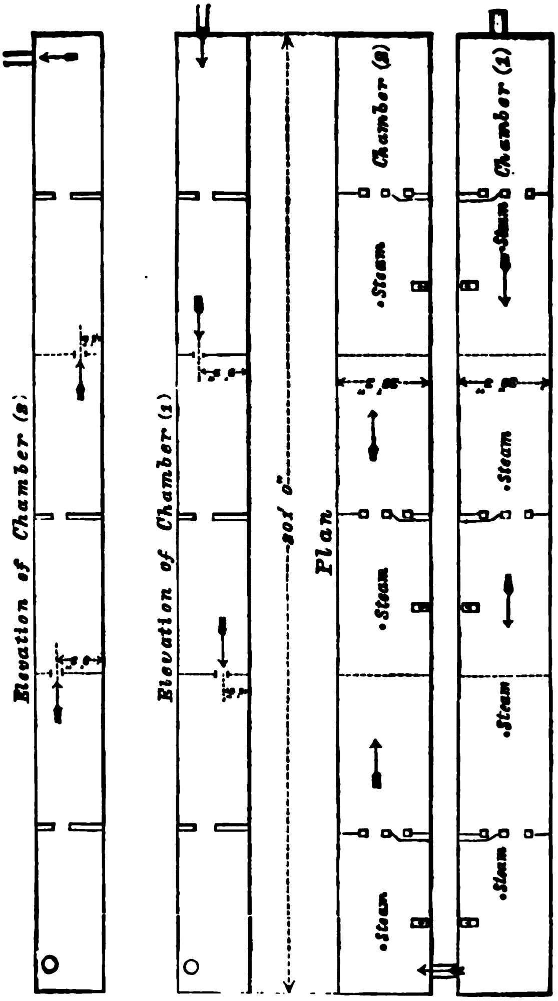
Secondly—The composition of the gases in the various chambers of a series, as calculated for a typical case.

The question as to what *zone* or *level* of the leaden chamber it is in which the production of the sulphuric acid chiefly takes place has now to be examined.

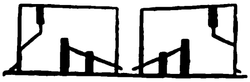
Reasoning from his experimental figures (which I have previously shown to be fallacious), Mr. Smith concluded that the chief portion of the reaction took place in the lower portion of the chamber, and thus he recommended low chambers of considerable length. Various other experiments have been made by others to elucidate the points now in question. Hasenclerer suspended trays in the chamber at different levels, and estimated the acid produced in a given time; but I have not been able to obtain any details of his experiments. Deacon also has made an interesting series of experiments on the amount of acid produced at various points of a single chamber, as measured by gauges placed close to the sides of the chamber at different levels. From the results he obtained he concluded that the statements of Smith were erroneous, and that, judging from his results—chiefly those of a series of gauges placed at the outlet end of the chamber—there was, taking averages, about 80 per cent. of the total acid produced in the top 3 or 4 feet of the chamber.

About a year ago, a series of chambers being laid off for repairs gave me the opportunity of making arrangements, with the purpose of investigating in a more complete way than has yet been done the question of the region of action in the chamber.

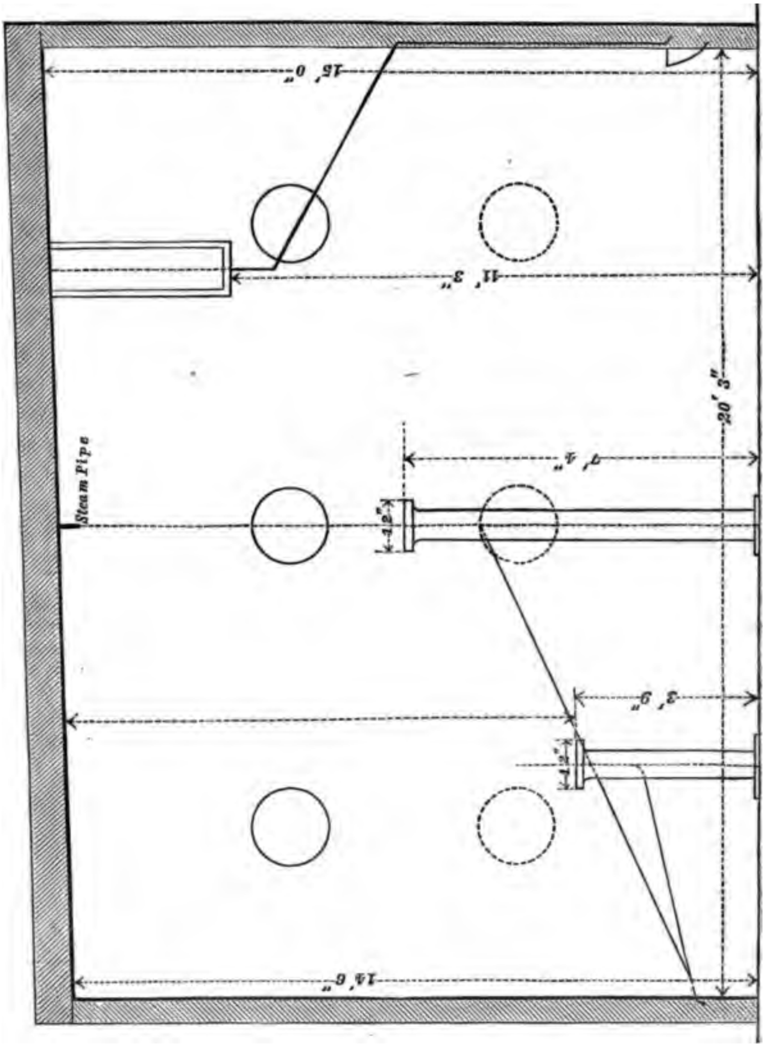
The series of chambers are shown on the drawing, and consist of two long chambers 201′ × 20′ 3″ 15′ × 6″. These are each divided into 3 sections by curtains, which have each openings in them alternately at top and bottom, the passage of the gas being indicated by arrows.



Plan of No. 1 Series of Chambers.—Scale, 40 feet to one inch.



Across the centre line of each section were arranged a series of sampling apparatus, consisting, firstly, of ordinary drip pockets on each side of the chambers, about 3 feet from the bottom; and, secondly, of three leaden trays, exactly one foot square each, and communicating with the outside of the chambers by means of a lead pipe. These gauges were supported on leaden columns at heights of 3′ 9″, 7′ 4″, and 11′ 3″ respectively, above the bottom of the chamber.



Cross Section, No. 1 Series of Chambers.—Scale, ¼ of an inch to the foot.

During the first series of experiments the trays were left uncovered, and a record was kept for some months of the daily yield of acid in bulk and specific gravity. Considerable irregularity was found to arise from the wrinkles in the roof of the chamber causing the acid condensed on the roof surface to drip more from one point than from another, and as these creases or wrinkles change their form and direction from time to time from the motion of the lead, caused by expansion and contraction, under the continual changes of temperature, the amount of acid caught in the trays varied now and then considerably from this cause. To avoid this, covers were arranged to hang from the roof, and in such a way as to shield the gauge trays from any drip from the roof. These covers also could be raised or lowered as required, and a set of results were obtained, with the covers close up to the roof of the chamber and another series with the covers lowered so as to include exactly one cubic foot of space above the gauge trays.

Calculating out the average of nineteen weeks' daily results on the first system, where no covers were used, and taking the roof or highest tray as yielding 100 parts of acid, the amounts yielded in same time by the middle and bottom trays is given in the Table following:—

NINETEEN WEEKS' AVERAGE—No Covers used on Trays.

Gauge Position.	No. 1 Chamber.		No. 2 Chamber.		No. 3 Chamber.		No. 4 Chamber.		No 5 Chamber.		No. 6 Chamber.	
	Ratio.	°Twad	Ratio.	°Twad	Ratio.	°Twad	Ratio.	°Twad	Ratio.	°Twad	Ratio.	°Twad
Roof,	100	125	100	140	100	130	100	109	100	84	100	88
Middle,	100·1	122	95·2	132	13·5	128	81·4	111	106	79	72·1	87
Bottom,	102·4	123	103	136	113·8	127	87·5	115	110·9	70	63·9	81

Reducing these figures to the basis of 100 of O.V. made in each chamber as found by the gauges we have—

NINETEEN WEEKS' AVERAGE—No Covers used on Trays.

Chambers.		1	2	3	4	5	6
Per 100 of Acid made in	Top Tray, .	33·0	33·0	30·5	37·1	31·5	42·3
	Middle Tray,	33·1	32·2	34·6	30·2	33·5	30·5
	Bottom Tray,	33·9	34·8	34·9	32·7	35·0	27·2
Percentage of Total Acid made in each Chamber,	.	26·1	31·3	20·4	11·8	7·9	2·4

As previously explained, in order to avoid risk of the surface condensation of the roof from affecting the results, covers were slung over the trays, and in the next series of experiments were kept just under the roof of the chamber, thus leaving a clear space from each of the trays to the top of the chamber. The results are given in the following Tables:—

WEEKLY AVERAGE—COVERS IN USE, CLOSE UP TO ROOF OF CHAMBERS.

Position of Gauge.	No. 1 Chamber.		No. 2 Chamber.		No. 3 Chamber.		No. 4 Chamber.		No. 5 Chamber.		No. 6 Chamber.	
	Ratio.	°Twad	Ratio.	°Twad	Ratio.	°Twad	Ratio.	°Twad	Ratio.	°Twad	Ratio.	°Twad
Roof,	100	128	100	139	100	103	100	85	100	70	100	80
Middle,	105·8	134	80	134	111·7	106	77·4	80	74·3	64	67·8	70
Bottom,	83·6	128	112·5	132	112·4	104	97·3	84	75·2	70	72·1	73

Reducing, as in the former case, these figures to the basis of 100 of O.V. in each chamber as found by the gauges, we have—

WEEKLY AVERAGE—COVERS IN USE, CLOSE UP TO ROOF OF CHAMBERS.

CHAMBERS.		1	2	3	4	5	6
Per 100 of Acid made in	Top Tray, .	34·54	34·11	30·85	36·4	40·0	40·4
	Middle Tray,	36·55	27·5	34·46	28·2	29·0	28·2
	Bottom Tray,	28·91	38·4	34·69	35·4	31·0	31·4
Percentage of Total Acid made in each Chamber, .		38·4	35·2	15·6	6·2	3·2	1·4

In the previous experiments each of the three gauge trays had a different height of chamber space above it, and it was to be expected that each tray should exceed in yield that next above it, by the amount of acid formed in the space between the two. This is rarely the case. We shall examine this point further on.

To determine the relative formation of acid in an equal chamber space at the different levels of the chamber, the covers were now lowered until there was exactly one cubic foot of space enclosed between the tray and the cover, and another long series of results obtained. These are embodied in the following Tables:—

WEEKLY AVERAGE—Covers in use, placed one foot above Trays.

Position of Gauge.	No. 1 Chamber.		No. 2 Chamber.		No. 3 Chamber.		No. 4 Chamber.		No. 5 Chamber.		No. 6 Chamber.	
	Ratio.	°Twad.	Ratio.	°Twad.	Ratio.	°Twad.	Ratio.	°Twad.	Ratio.	°Twad.	Ratio.	°Twad.
Roof,	100	125	100	132	100	123	100	116	100	104	100	103
Middle,	95	123	70	119	106	125	87	115	95	102	85	98
Bottom,	84	120	99·6	128	120	126	93	115	92	98	97	100

Reducing these figures to the basis of 100 parts O.V. in each chamber as found by the gauges, as in the previous cases, we have—

WEEKLY AVERAGE—Covers in use, placed one foot above Trays.

Chambers.		1	2	3	4	5	6
Per 100 of Acid made in	Top Tray,	36·18	37·7	31·7	36·3	35·6	34·6
	Middle Tray,	33·8	26·5	33·6	31·0	32·8	32·4
	Bottom Tray,	30·02	35·8	34·7	32·7	31·6	33·0
Percentage of Total Acid made in each Chamber,		32·0	29·0	17·5	13·7	5·4	2·4

These various results will be better understood by placing them side by side, and in order to avoid the slight variations from the mean figures, it will be advisable to take the production at the three different levels for the whole of the chambers. We then obtain the following figures:—

Percentage of Acid made in each Tray.	Nineteen Weeks' Average. No Covers Used.	Weekly Averages. Covers Used, close to Roof of Chamber.		Weekly Averages. Covers Used, at 1 foot above Trays.
		a	*b*	
Top Tray,	35	36	36	35
Middle Tray,	32	31	33	32
Bottom Tray,	33	33	31	33

These results would therefore seem to show the somewhat startling fact that, broadly speaking, the same amount of acid was caught by each of the three sets of trays. As it is clear that all the acid which is formed in the upper portion of the chamber must, in order to reach the bottom as liquid sulphuric acid, fall through the intervening space between the region of its formation and the chamber floor.

It would follow that all the sulphuric acid must have been produced within the space between the roof of the chamber and the top tray, this space being 3 feet 6 inches deep, or say one-fourth of the total height of the chamber.

For it is evident that, if we indicate by the letters A, B, and C the quantities made in the zones or levels of the chambers enclosed between—

1st. The roof and the top tray.
2nd. The top and middle tray.
3rd. The middle and bottom trays

respectively, we would have as the theoretical yield of the trays—

Top $= A$.
Middle $= A + B$.
Bottom $= A + B + C$.

But we have already seen that, speaking broadly, $A = A + B$, and also that $A = A + B + C$; and it is evident that therefore neither B nor C can have any value, and that no acid has been formed within zones 2nd and 3rd.

To elucidate this point still further a number of analyses of the gases of one of the chambers of No. 1 set were made, with the following results:—

TOP.

SO_2 grams per litre,	·126 as SO_3
SO_3 ,, Total,	·159 ,,
Per cent. existing as SO_3,	21 of total.
,, Oxygen after absorption of Acids,	10·7
,, ,, oxidizing SO_2,	9·0

MIDDLE.

SO_2 grams per litre,	·112 as SO_3
SO_3 ,, Total,	·159 ,,
Per cent. existing as SO_3,	26 of total.
,, Oxygen after absorption of Acids,	10·9
,, ,, oxidizing SO_2,	9·3

BOTTOM.

SO_2 grams per litre,	·108 as SO_3
SO_3 ,, Total,	·161 ,,
Per cent. existing as SO_3,	33 of total.
,, Oxygen after absorption of Acids,	10·9
,, ,, oxidizing SO_2,	9·3

[illegible] —

	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	10	10	[illegible]
[illegible]	5	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Specific gravity [illegible] compared with air—

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Air	1·000
[illegible]	[illegible]
Water	773·000
NO_2	1·589
Steam [illegible]	·47

The temperature of the chambers being somewhere about 150° to 170°, the nitrous compounds must be assumed to be NO_2, and, according to the experiments of Playfair and Wanklyn, the specific gravity will then be as above, 1·589.

The average specific gravity of the gases may be taken say as 2·00, while the H_2SO_4 has a specific gravity of 1430·00. It may be that the vaporous condition of the latter may modify to some extent this figure relatively as to effect, but the difference is so enormous as to leave no doubt of the relative positions occupied in the chamber, and if then the gases occupy the higher levels, there necessarily will the formation of the sulphuric acid take place.

There are, no doubt, irregularities in the yield as obtained at any point of the chamber, but this is accounted for at once if we observe the constant whirl and current of the gases, caused chiefly by the strong effect of the steam jets which enter the chamber, with considerable velocity, as well as by the general current towards the exit caused by the draught.

To the question, what then does this teach us as to the best form of chamber? I would reply—

That it seems as if the form of chamber was not a material point, the chief factor being plenty of chamber space for the work to be done. But experiences of low chambers has shown me that they are more apt to go out of order, and have a greater tendency to "go through," the scarcity of nitrous compounds at any time allowing, as it were, a wall of SO_2 to pass on from one end to the other, without mixing; whereas in high chambers there seems more chance of overtaking this by the additional supply of nitrous compounds introduced when the deficiency is discovered. Still it would be unsafe to conclude that high chambers were best, until the question of surface in connection with condensation has been considered, as well as what is a most difficult problem to solve, viz., which form of chamber can be worked with the least consumpt of nitrate of soda. I hope to take up the consideration of the latter point in a future paper. Meantime, I would point out that surface plays a most important part in the production of sulphuric acid. That the condensation of the acid on the surface of the lead is very large, may at once be seen on examining a sulphuric acid chamber while working. The acid will be heard falling in drops from the roof, and if the draught is quick enough to enable one to look in by a door the quantity will be seen to be very considerable indeed.

The idea of utilising surface in the manufacture of sulphuric acid was adopted by a Mr. Ward many years ago. He patented the use of a form of chamber in which a large number of sheets of glass were arranged in horizontal tiers, about an inch or two apart, so as to give an immense surface for condensation.

The following experiments were made to test the effect of surface on the production of sulphuric acid :—

A tray made of sheet lead, of as near as possible one foot square, was suspended in a small chamber, and the acid condensed in it in 24 hours was found to amount to—

718·75 grains H_2SO_4.

Twelve pieces of glass, measuring each 12 in. × 1 in., were now placed in a vertical position in the leaden tray, and kept 1 inch apart. The tray thus arranged was again exposed for 24 hours, and the acid found condensed was equal to—

1660 grains H_2SO_4.

Deducting from this the amount formerly obtained in the tray without the glass = 718·75, we have = 941·25 grains as condensed upon the glass. If we calculate the surface exposed we find = 12 square feet, and dividing the acid condensed on the surface by this figure we have = 78 grains per square foot as the amount condensed by the glass placed vertically.

The same glass was now placed in the tray in a horizontal position, and at the same distance apart. Again exposed for 24 hours, and the acid found condensed amounted to—

3270 grains H_2SO_4.

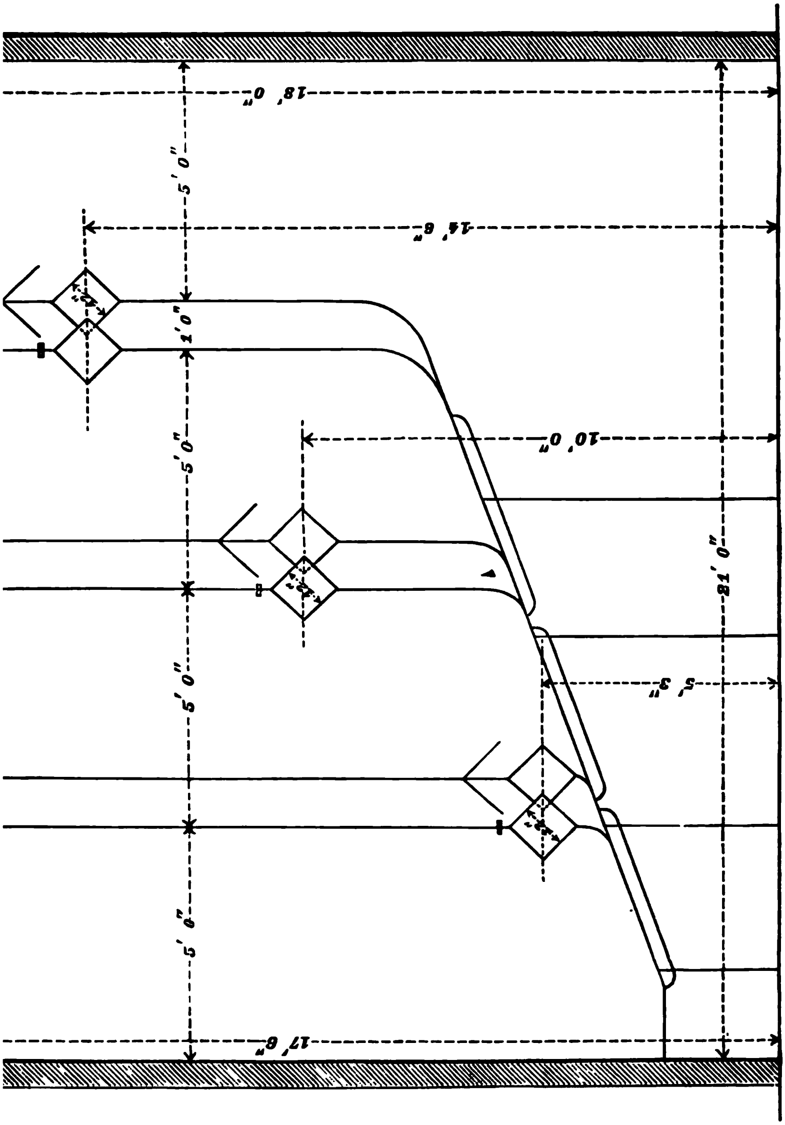
Deducting as before the amount obtained without the glass, 3270 − 718·75 = 2551·25 grains as condensed upon the glass, and 2551·25 ÷ 12 = 212·6 grains per square foot.

The relative proportions being—

Tray without glass - - - - - -	100
Tray with glass vertical - - -	231
Tray with glass horizontal - - -	455

The enormous increase (4½ times) in the condensation shows clearly what an important element—in the calculation of the most advantageous form of chamber—the surface available for condensation is. While this again is involved in the question as to cost of erection, a chamber of equal sides forming a cube will, of course, give the maximum of space with the minimum of lead; but it is evident that this form would be the worst that could be adopted, so far as surface condensation is concerned.

Co investigate the effect of surface still further another set of mbers was arranged with a series of drips, trays, &c., in nner shown in the accompanying drawings.



Drawing A shows the arrangement of the lead surfaces used to condense the acid upon. These were arranged in pairs, one of each pair being simply a small tray of lead, so arranged on the hanging support as to prevent acid dripping down it, and being measured as having been condensed on the leaden surface of one square foot; the other one of the pair had a screen so arranged over it that no acid descending from the upper portion of the chamber could be deposited, or would fall on the square foot of leaden surface.

These pairs of surface condensers were arranged at three different levels of the chamber, as shown in the drawing, at heights respectively of 5′ 3″, 10′, and 14′ 6″ from the bottom of the chamber, and were so arranged as to allow all the acid caught on them to run off, through a pipe to the outside of the chamber, when it was caught, and measured at fixed hours of the day.

These results were tabulated daily, and the observations were extended over several months, the average amounts being—

	For the Uncovered Trays.	Covered Trays.
High, - -	100 O.V. (H_2SO_4)	100 O.V. (H_2SO_4).
Middle, -	114 ,,	111 ,,
Bottom, -	165 ,,	146 ,,

representing as yield of

High,	- say	61 % of total,	68 % of total.
Middle,	,,	8 ,,	7 ,,
Bottom,	,,	31 ,,	25 ,,

Thus confirming very completely the previous results, and showing that the larger portion by far of the acid is produced in the upper portion of the chamber.

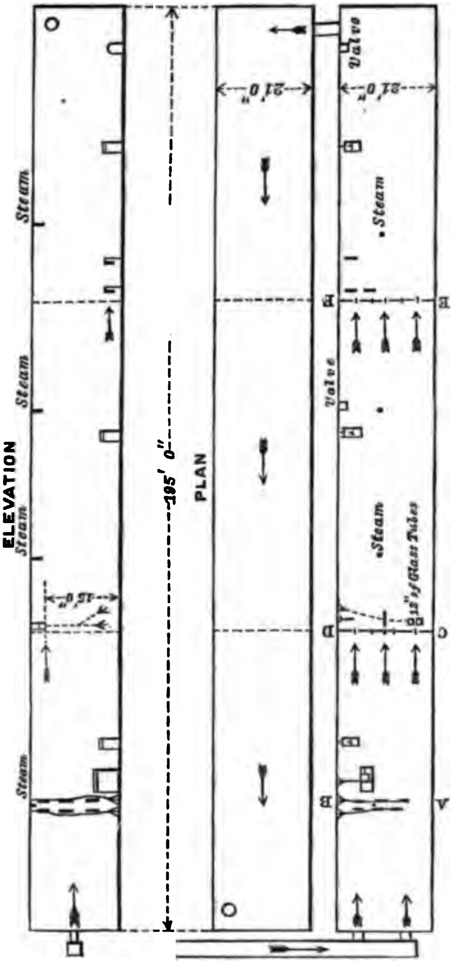
Drawing B.—The set of chambers in which these "surface condensers" were arranged consisted of two long chambers divided by curtains into 3 divisions each, or 6 divisions in all.

In the first division were placed the six trays shown in drawing A, each one foot square, and in addition to these a series of flat trays, exposing surfaces of one square foot, two square feet, and four square feet respectively, with a view of determining the condensation per square foot of surface. These were placed close together so as to be as nearly as possible under the same conditions.

The result obtained over a long period showed an average condensation of—

On the 1 square foot, - -	100·
„ 2 „ - -	199·2
„ 4 „ - -	403·

or in proportion to the surfaces exposed.

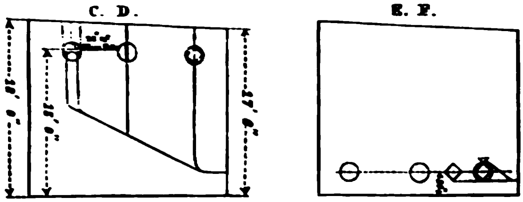


DRAWING B. Plan of No. 2 Series of Chambers.—Scale, 40 feet to one inch.

In the second division of the chambers there was placed, first one "surface condenser," with its flat surface facing the current of gas entering the second division by one of the openings in the curtain which divides it from the first division, so arranged that the acid condensed on each of its sides could be caught separately, and the amount produced when a current of the gases impinged upon the lead surface could be compared with that produced upon what may be called the "lee" side of the same condenser.

A similar "surface condenser" was placed edge on to the current of gas at the other opening in the same curtain, so that both surfaces might be exposed to the rush of the current of the gases. (See Drawing C.)

DRAWING C. Cross Section, No. 2 Series of Chambers.
Scale, 20 feet to one inch.



The results obtained showed that the amount condensed on a given surface was very much in proportion to the impact of the gases—

Flat surface facing gaseous current	gave =	100
„ lee side,	„ „	78
Double surface edge on to current,	„ „	175

Opposite the third opening in the curtain there were placed two other leaden trays, each one foot square. One of these had in addition a number of slips of glass, equal in surface to one square foot, placed vertically.

The amounts condensed were in proportion of—

Tray alone, - - - -	100
„ with glass surface, - -	192

These results corroborated those previously mentioned.

I have thus endeavoured to put before you my views as to the distribution and condensation of the gases in the sulphuric acid chambers, and I would now express the hope that those of you who are interested in the manufacture should, as opportunity occurs, investigate further the question. It involves an immense amount of actual work, and requires a great deal of patient waiting ere a sufficient amount of data are obtained upon which we may found our reasoning. This obtains in all research, but is labour well bestowed, and returns ultimately a good reward.

MINUTES OF SESSION.

Minute of Extraordinary General Meeting of the PHILOSOPHICAL SOCIETY OF GLASGOW, incorporated under the Companies' Acts, 1862, 1867, and 1877, of date 30th April, 1879, held within the LIBRARY, 276 Sauchiehall Street, on Wednesday, the twenty-seventh day of August, eighteen hundred and seventy-nine, at eight o'clock, p.m.

PRESENT—

Drs. Andrew Fergus,
J. R. Wolfe,
D. C. M'Vail,
Hugh Miller,
John Glaister,
Robert Grieve,
Messrs. Archibald Robertson,
John Jex Long,
Arthur Herriot,
John Anderson,
James Barclay,
Patrick Falconer,
R. L. Brown,
W. P. Buchan,
Alexander Scott,
Messrs. James Beveridge,
John Foulds,
George Watson,
John Kerr,
James Hunter,
George Munsie,
T. L. Watson,
J. B. Gilmour,
James M'Aulay,
George Murray,
Sigismund Schuman,
James Smith,
J. Robertson, *Librarian*,
John Mann, *Treasurer*,
E. M. Dixon, *Secretary*.

Also, in attendance, Mr. David T. Maclay, of Messrs. Maclay, Murray, & Spens, Writers, Agents for the Society.

Dr. Fergus, *President*, in the Chair.

The Chairman mentioned the object of the Meeting, and called upon Mr. Maclay, who explained at some length the purpose and nature of the resolution to be submitted.

The Chairman then proposed the following special resolution:—"That the Council be, and are hereby authorized to borrow in name of the Society, money to an extent not exceeding two thousand five hundred pounds sterling, on the security of the Society's interest in the ground in Bath Street, Glasgow, recently purchased in conjunction with the Institution of Engineers and Shipbuilders in Scotland, and in the buildings now being erected thereon, or, if necessary, to concur with the said Institution in borrowing a sum of money not exceeding five thousand pounds on the security of the interests of the Society and the said Institution in the said ground and buildings, and to grant to the lenders a bond and disposition in security in the usual form, binding the Society and the said Institution jointly and severally for repayment of the whole loan, interest thereon, and consequents;" which was seconded by Mr. W. P. Buchan, and unanimously agreed to.

It was agreed to hold another Meeting of the Society for the confirmation of the foregoing resolution, in the same place, on *Wednesday, 17th September next*, at same hour.

Minute of Extraordinary General Meeting of the PHILOSOPHICAL SOCIETY OF GLASGOW, incorporated under the Companies' Acts, 1862, 1867, and 1877, of date 30th April, 1879, held within the SOCIETY'S LIBRARY, 276 Sauchiehall Street, Glasgow, on Wednesday, the seventeenth day of September, eighteen hundred and seventy-nine, at eight o'clock, p.m.

PRESENT—

Drs. Andrew Fergus,
William Wallace,
Henry Muirhead,
J. B. Russell,
D. C. M'Vail,
W. T. Gairdner,
Hugh Miller,
James Morton,
John Glaister,
J. R. Wolfe,
Robert Renfrew,

Messrs. J. B. Gilmour,
Edward A. Wünsch,
T. L. Watson,
George Watson,
W. P. Buchan,
Robert Westlands,
William Gorman,
Daniel Miller,
W. G. Lindsay,
Campbell Douglas,
John Jex Long,

Messrs. Alexander Scott,
Archibald Robertson,
J. J. Coleman,
Arthur Herriot,
Sigismund Schuman,
James Park,
Archibald Hewat,
Robert R. Stephen,
John Kerr,

Messrs. James M'Aulay,
Francis Smith,
John Knox,
Michael Connal,
William Galbraith,
John Robertson, *Librarian*,
John Mann, *Treasurer*,
E. M. Dixon, *Secretary*,

and other Members of the Society.

Also in attendance, Mr. John A. Spens, of Messrs. Maclay, Murray, & Spens, Writers, Agents for the Society.

Dr. Andw. Fergus, *President*, in the Chair.

Mr. Spens having explained the purpose of the Meeting, and several questions by Members having been asked and answered, the Chairman moved, "That the Society do now confirm the Special Resolution which was unanimously passed at the Extraordinary General Meeting of the Society, held in the same place on 27th ultimo, viz.:—'That the Council be, and are hereby authorized to borrow in name of the Society, money to an extent not exceeding two thousand five hundred pounds sterling, on the security of the Society's interest in the ground in Bath Street, Glasgow, recently purchased in conjunction with the Institution of Engineers and Shipbuilders in Scotland, and in the buildings now being erected thereon, or, if necessary, to concur with the said Institution in borrowing a sum of money not exceeding five thousand pounds on the security of the interests of the Society and the said Institution in the said ground and buildings, and to grant to the lenders a bond and disposition in security in the usual form, binding the Society and the said Institution jointly and severally for repayment of the whole loan, interest thereon, and consequents.'"

This motion was seconded by Mr. John Jex Long, and unanimously agreed to.

November 5, 1879.

The Session of the Philosophical Society of Glasgow was opened this evening at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Regular Meeting of the Society, held on 30th April, with those of the four Extraordinary General Meetings of the Society, held on 14th May, 20th May, 27th August, and 17th September, respectively—all of which appeared *in extenso* in the notice calling this Meeting—were held as read, and were confirmed, and signed by the Chairman.

The following were proposed as Members, viz.:—

Mr. David T. Maclay, Writer, 169 West George Street. Recommended by Dr. Fergus, Mr. E. M. Dixon, and Mr. John J. Long.

Mr. John A. Spens, Writer, 169 West George Street. Recommended by Dr. Fergus, Mr. John J. Long, and Mr. E. M. Dixon.

Mr. Robert Franklin Muirhead, B.Sc., 189 Renfrew Street. Recommended by Dr. Muirhead, Dr. Fergus, and Mr. J. Mann.

Mr. John Henderson, Jun., Shipbuilder, 4 Crown Terrace, Dowanhill. Recommended by Dr. Fergus, Mr. John Mann, and Dr. Muirhead.

Mr. Robert Livingston, Edge Tool Maker, 263B Argyle Street. Recommended by Dr. Fergus, Dr. Muirhead, and Dr. Christie.

Mr. James Dickie, Merchant, 7 Claremont Terrace. Recommended by Mr. John D. Thomson, Mr. W. R. W. Smith, and Mr. J. Mann.

Dr. Thomas Barr, 65 Great Western Road. Recommended by Dr. Fergus, Dr. Russell, and Dr. Muirhead.

Dr. Fergus delivered the President's Opening Address, in which he treated of Preventive and State Medicine.

On the motion of Dr. Cameron, M.P., the thanks of the Society were unanimously awarded to Dr. Fergus for his address.

At the request of the President, Dr. Stirton made a few remarks regarding the forthcoming conference of the Cryptogamic Society of Scotland, proposed to be held in Glasgow in the autumn of 1880. The substance of these remarks is as follows:—He said,

"It was proposed in the first instance to organize a large local committee; but, in order to determine the scale of operations, it was necessary as a preliminary to start a Guarantee Fund, and the sum of £100 was considered amply sufficient.

"The main object of the Society was the investigation of the Cryptogamic Flora of the West of Scotland. Various excursions to interesting places would be made, and the different collections exhibited in some hall in the city. Besides the assistance of the scientific men expected from all parts of the United Kingdom, it would be necessary to secure the co-operation of others, as gamekeepers, &c., resident near the various botanical localities. To meet the expenses it was proposed to charge a shilling as the price of admission to the exhibition, and in the event of 2000 tickets being sold, the guarantors would not be called on to disburse any part of their subscriptions. The most interesting part of the exhibition would be the Fungi of the West of Scotland, and of these many thousands might fairly be expected. These plants would be arranged with a view to their properties, and generally in two groups, according as they were edible or poisonous. Besides this section of botany, there would be groupings of ferns, mosses, sea-weeds, and lichens, as well as a fringe of the more gorgeous flowering plants secured from the various private collections in the neighbourhood. At this exhibition several members of the Cryptogamic Society would also be prepared to give addresses in the different sections. In addition to the exhibition it was contemplated to have a dinner, at which various preparations of edible fungi would constitute a part of the entertainment, or figure as side dishes, or play the part of condiments. Whether a *conversazione* on kindred subjects would be held would depend upon the decision of the Local Committee, and in general the whole course of proceedings would be regulated by this Committee.

"In order the more readily to secure the requisite Guarantee Fund, it has been recommended that individual subscription should range from 10s. to £2."

Dr. Stirton's remarks were very favourably received, and it was resolved to incorporate them in the Minutes of the Meeting, in order that the attention of Members, who might be willing to aid by subscriptions to the Guarantee Fund, might be drawn to the subject.

Mr. Alexander Whitelaw and Mr. Sigismund Schuman were appointed Auditors of the Treasurer's Accounts.

Dr. Wallace gave notice of motion for next Meeting:—

"That means be taken to ascertain the feeling of Members as to whether the night of Meeting should be altered."

November 19, 1879.

The Seventy-eighth Annual General Meeting of the Philosophical Society of Glasgow, for the election of Office-Bearers, and other business, was held this evening at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

The following were proposed as Members, viz.:—

Mr. John Brown, Accountant, 128 Hope Street. Recommended by Dr. J. Christie, Dr. H. Muirhead, and Mr. Archd. Robertson.

Mr. Charles A. Fawsitt, Chemist, St. Rollox Works. Recommended by Mr. James Mactear, Mr. John Mann, and Dr. Henry Muirhead.

Mr. John Miller, Writer, 179 West George Street. Recommended by Mr. John Mann, Dr. Wm. Wallace, and Dr. Henry Muirhead.

Mr. William Murdoch, Engineer, 30 Hope Street. Recommended by Mr. James Manwell, Dr. Wm. Wallace, and Mr. John Mann.

Mr. David Laidlaw, Chaseley, Skelmorlie. Recommended by Mr. John Honeyman, Dr. Wm. Wallace, and Mr. David Thomson.

Mr. Robert T. Purvis, 176 Kent Road. Recommended by Mr. Robert Cochran, Dr. Andrew Fergus, and Dr. Wm. Wallace.

Mr. John Laird, Auctioneer, Royal Exchange Sale Rooms. Recommended by Mr. John Jex Long, Dr. Wm. Wallace, and Mr. E. M. Dixon.

Mr. Andrew J. Smith, Architect, 121 West Regent Street.

Recommended by Dr. J. E. Brodie, Dr. Andrew Fergus, and Mr. Sig. Schuman.

The following were elected Members of the Society, viz.:—

Mr. David T. Maclay, Writer, 169 West George Street.

Mr. John A. Spens, Writer, 169 West George Street.

Mr. Robert Franklin Muirhead, B.Sc., 189 Renfrew Street.

Mr. John Henderson, Jun., Shipbuilder, 4 Crown Terrace, Dowanhill.

Mr. Robert Livingston, Edge Tool Maker, 263B Argyle Street.

Mr. James Dickie, Merchant, 7 Claremont Terrace.

Dr. Thomas Barr, 65 Great Western Road.

Mr. E. M. Dixon, Secretary, read the Annual Report by the Council on the state of the Society, which was adopted and ordered to be printed in the *Proceedings.*

REPORT ON THE STATE OF THE SOCIETY, 1878-79.

1. *Membership.*—The number of Members on the Roll at the beginning of Session 1878-9 was 671. During the Session 22 new Members were admitted, and 1 was reinstated from the Suspense List, making in all 694. Of this number 28 have resigned; 11 have left Glasgow, their names being placed upon the Suspense List; 16 have died; 5 have been struck off for non-payment of annual subscriptions; and 1 has been elected an Honorary Member—leaving on the Roll at the commencement of the present Session 633.

2. *Sections.*—With the exception of the Mechanical and Physical Section, all the Sections have been in active operation throughout the Session, and have furnished a considerable part of the papers read before the Society, besides contributing to the Society's *Proceedings.*

3. *Future Accommodation of the Society.*—The Annual Report presented at the opening of last Session contained a statement of the steps that had, at that time, been taken in the way of providing new premises for its accommodation. On the present occasion the Council has the satisfaction of adding that the progress made in

the erection of the new building is such as to warrant the confident expectation that the next Session of the Society will be opened in it, and that the valuable Library of the Society may be safely transferred to it even before that time. At present the mason work of the new building is very nearly finished, and the process of roofing it in, which has already been commenced, will not occupy many days.

The new building, it may be added, will consist of three floors and a basement flat. The first floor will be devoted to a Library and a Reading-Room, the former of which will measure about 52 feet by 20 feet, and the latter 30 feet by 20 feet. The Hall for Meetings of the Society and a Council Room will occupy the second floor, the former measuring about 52 feet by 30 feet, and the latter 30 feet by 20 feet. A room for Meetings of Sections, and a Council-Room for Sections, will occupy the third floor. In the basement flat will be found a house for a janitor or other officer of the Society, a heating chamber, two large fire-proof safes, and ample space for storage. Special attention has been given to the ventilation of the building generally; and as regards the Meeting Hall in particular, every needful appliance for the delivery of experimental lectures has been considered and provided for.

4. *The Incorporation of the Society.*—The Council desire to congratulate Members upon the improvement made in the status of the Society by its incorporation.

The Audited Statement of Accounts for Session 1878-79, by Mr. Mann, the Treasurer, having been printed in the circular calling the Meeting, was held as read, was approved of, and ordered to be printed in the *Proceedings.*

ABSTRACT OF TREASURER'S ACCOUNT.

SESSION 1878-79.

Dr.

1878.—Nov. 1.			
To BALANCES from last Session, viz.:—			
(1) Investment with Corporation Water Commissioners,		£400 0 0	
(2) Investment with Board of Police,		350 0 0	
(3) In City of Glasgow Bank,		280 0 0	
		£1,030 0 0	
Less due Treasurer,		240 1 3¼	£789 18 8¾
1879.—Oct. 31.			
To Entry-money from 22 New Members, at 21s.,		£23 2 0	
,, Annual Dues from 2 Original Members for 1878-79, at 5s.,	£0 10 0		
,, Annual Dues from 572 Ordinary Members for 1878-79, at 21s.,	600 12 0		
,, Annual Dues from 21 New Members for 1878-79, at 21s.,	22 1 0		
		623 3 0	
,, Life Subscription from 1 Ordinary Member,	£10 10 0		
,, Life Subscription from 1 New Member,	10 10 0		
		21 0 0	
			667 5 0
,, ARCHITECTURAL SECTION—			
Associate Fees since 30th Oct., 1872,			8 0 0
,, BIOLOGICAL SECTION—			
2 Associates for 1876-77, at 5s.,		£0 10 0	
1 do. 1877-78, at 5s.,		0 5 0	
1 do. 1878-79, at 5s.,		0 5 0	
			1 0 0
,, CHEMICAL SECTION—			
2 Associates for 1876-77, at 5s.,		£0 10 0	
6 do. 1877-78, at 5s.,		1 10 0	
35 do. 1878-79, at 5s.,		8 15 0	
			10 15 0
,, Corporation of Glasgow, interest on "Exhibition Fund" for year to Whitsunday, 1879—less Income Tax,		£48 19 2	
,, Interest from Banks,		6 10 4	
,, Do. from Corporation Water Commissioners' Bond (till Whitsunday, 1879, when uplifted)—less Income Tax,		15 13 4	
" Do. from Board of Police Bond (ditto),		13 14 2	
			84 17 0
,, *Proceedings* sold,			0 4 0
,, Balance due Treasurer,			207 14 11½
			£1,769 14 8

1879.—Oct. 31. Cr.

By Salary to Secretary, ...	£75 0 0	
,, Salary to Sub-Librarian, . . .	61 8 7	
,, Salary to Assistant in Library, . .	18 3 0	
,, Reporting Sectional Discussions, . .	3 3 0	
,, Allowance for Treasurer's Clerks, . .	15 0 0	
,, Fees of Lodging Special Resolution, .	0 10 3	£173 4 10
,, New Books, £27 19s. 11d.; Periodicals, £27 3s. 6d.; Foreign Periodicals, £3 4s.,	£58 7 5	
,, Binding, ...	14 0 0	
,, Printing *Proceedings*, Circulars, &c., .	126 3 0	
,, Lithographs and Woodcuts for *Proceedings*, &c.,	26 17 0	
,, Postage and delivery of Circulars, Letters, and Parcels, ...	32 19 0½	
,, Stationery, ...	1 17 6	260 3 11½
,, Rent of Rooms till Whitsunday, 1879, .	£100 0 0	
,, Do. Galleries (two Sessions), . .	60 0 0	
,, Fire Insurance for £5,400, . . .	13 13 4	
,, Furnishings and Repairs, . . .	2 10 3	
,, Gas, £10 8s. 6d.; Coal, £1 11s. 6½d.; Cleaning, 18s. 6d., ...	12 18 6½	
,, Postages, &c., per Treasurer, . .	2 14 8	
,, Sundries in Library, ...	1 7 11½	
,, Gasfittings for Exhibition of Sugg's Burners,	2 10 0	195 14 9
,, Subscriptions to Societies—		
Ray Society, 1879, ...	£1 1 0	
Palæontographical Society, 1879, .	1 1 0	2 2 0
,, Biological Section—		
Expenses per Secretary of Section, ...		0 7 6
,, Chemical Section—		
Expenses per Treasurer of Section, ...		1 18 11
,, Architectural Section—		
Expenses (since 30th October, 1872) per Treasurer of Section, ...		11 2 8½
,, Bath Street Buildings—		
Society's half of Price of Ground, .	£600 0 0	
Do. Instalments of Mason Work, &c., ...	525 0 0	1,125 0 0
		£1,769 14 8

Glasgow, 13*th November*, 1879.—We, the Auditors appointed by the Society to examine the Treasurer's Accounts, for the year 1878-79, have examined the same, of which the above is an Abstract, and found them correct, the Balance due to the Treasurer at 31st October last being Two hundred and seven pounds fourteen shillings and elevenpence halfpenny, after payments of Eleven hundred and twenty-five pounds sterling towards the price of Ground and Buildings in Bath Street.

(Signed) ALEXANDER WHITELAW.
Sig. SCHUMAN.

Mr. John Robertson, Librarian, read the Annual Report on the state of the Library, which was adopted and ordered to be printed in the *Proceedings.*

LIBRARY COMMITTEE'S REPORT.

In February last Mr. Walker, the Sub-Librarian, died, and Mr. Thomas Napier was appointed his successor. Since then the work of repairing the imperfections of the Library has been vigorously carried on, numerous deficiencies have been supplied, and the Committee are now able to say that the Library is rapidly attaining a creditable condition. It contains at present 7800 volumes, besides pamphlets, and parts of works.

Since last Report correspondence has been opened up with five additional Societies, viz.:—The Leicester Literary and Philosophical Society; the Manchester Scientific Students' Association; the North Staffordshire Institute of Mining and Mechanical Engineers; the Birmingham Philosophical Society; and L'Ecole Polytechnique. Exchanges of *Transactions* are at present made with 102 Societies.

During the year there have been added to the Library 325 volumes, and 53 pamphlets. 17 periodicals are received weekly, 5 fortnightly, 32 monthly, and 13 quarterly. 185 volumes have been bound or rebound, and 85 are in the hands of the binder. 113 books and pamphlets have been presented to the Library, and the thanks of the Society are due to the donors. Acknowledgment of these will be found in the *Proceedings,* where a full list of all the additions during the past year—required by the Constitution to be presented to this Meeting—has already been published.

A vote of thanks to the Secretary, Librarian, and Treasurer, was moved and carried unanimously.

The Society then proceeded to the election of Office-bearers.

It was moved by Dr. William Wallace, the retiring Vice-President, that Mr. Thomas Muir, M.A., F.R.S.E., be elected a Vice-President of the Society for the next three years, which was seconded by Mr. John Jex Long, and carried unanimously.

The Chairman moved the re-election of Mr. John Robertson, the Librarian, and Mr. John Mann, the Treasurer, respectively, which motions were carried by acclamation.

The Chairman stated that Mr. Dixon, the Secretary, had agreed to continue to act, if re-elected, at least until the joint occupation of the new premises is commenced, when the subject might be reconsidered—he getting the assistance of Mr. Mann, the Treasurer, with regard to the details, as during the past year—and therefore moved the re-election of the Secretary, which was carried unanimously.

The Chairman stated that the four gentlemen who retire from the Council by rotation at this time were Professor Gairdner, Messrs. Thomas Muir, James Thomson, and J. J. Long, the latter being eligible for re-election, having been only one year in the Council.

Mr. James Thomson, F.G.S. (one of the Members of Council who now retires), proposed the following gentlemen as Members of Council in place of the four who retire by rotation, viz.:—Dr. William Wallace, Mr. John Jex Long, Mr. Michael Connal, and Dr. Eben. Watson.

Mr. Schuman proposed Mr. J. B. Murdoch; Mr. Mayer proposed Mr. Nathaniel Dunlop; Mr. Mactear proposed Dr. William Ramsay; and the Society then balloted for four members.

Messrs. John M'Gavin, John Robertson, Archibald Hewat, and William Dennison, were appointed Scrutineers of the votes.

The Scrutineers reported that the following had the greatest number of votes, viz.:—

Dr. William Wallace, ...	81 votes.
Mr. Michael Connal, ...	62 „
Mr. John Jex Long, ...	49 „
Dr. Eben. Watson, ...	44 „

These gentlemen were, therefore, declared by the Chairman to have been duly elected Members of the Council.

Mr. W. J. Millar, C.E., read a paper "On the Transmission of Sounds by Wires without the aid of Electricity, and on Simple Forms of Receiving Instruments for the Microphone," which elicited some questions and remarks, and for which the author received the thanks of the Society.

Mr. John Mayer, F.C.S., made a statement in continuation of some observations laid before the Society by him on 16th April last, with reference to the manufacture of Cleveland Steel by the Thomas-Gilchrist process, and exhibited specimens of special bricks—from magnesian limestone—now being manufactured for the process by Mr. James Dunnachie, of the Star Fire Brick

Works, Glenboig. Mr. Mayer received the thanks of the Society for his communication.

Dr. William Wallace moved, in terms of notice given at last Meeting—"That means be taken to ascertain the feeling of Members as to whether the night of Meeting should be altered," which was seconded by Mr. Nathaniel Dunlop. Mr. W. P. Buchan moved as an amendment "the previous question," which was seconded by Mr. Mitchell. On a division, the votes for the motion were 21, and for the amendment 30, which was accordingly declared carried.

Mr. J. J. Coleman, F.I.C., F.C.S., made a statement with regard to the state of the "Graham Medal and Lecture Fund," instituted by a Committee of the Chemical Section, and gave notice of the following motion for next Meeting:—

"That the Society vote a sum of fourteen pounds to the fund, in respect of the expenditure of that sum on advertising, and printing cards of invitation to the Members of the Society and their friends, for the Inaugural 'Graham' Lecture on 22nd January last; and, further, that it is desirable that the Society approve of the capital fund being raised to three hundred and fifty pounds, as originally intended by the Committee, in order that it may be enabled to bear the expense of the Triennial Medal and Triennial Lecture arranged by its draft constitution."

December 3, 1879.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

The following were elected Members of the Society, viz.:—

Mr. John Brown, Accountant, 128 Hope Street.
Mr. Charles A. Fawsitt, Chemist, St. Rollox Works.
Mr. John Miller, Writer, 179 West George Street.
Mr. William Murdoch, Engineer, 30 Hope Street.

Mr. David Laidlaw, Chaseley, Skelmorlie.
Mr. Robert T. Purvis, 176 Kent Road.
Mr. John Laird, Auctioneer, Royal Exchange Sale Rooms.
Mr. Andrew J. Smith, Architect, 121 West Regent Street.

Dr. John Dougall, F.F.P.S.G., Lecturer on Materia Medica in the Glasgow Royal Infirmary School of Medicine, and one of the Vice-Presidents of the Sanitary and Social Economy Section, read a paper "On Disinfection by Acids," for which a vote of thanks, moved by the President, was heartily accorded by the Society.

Dr. Wm. Wallace, Gas Examiner for the City, then read a paper "On the Heating Power of Coal-Gas of different qualities," for which the thanks of the Society were awarded.

In absence of Mr. J. J. Coleman, F.I.C., F.C.S., from illness, Mr. Alex. Whitelaw, with consent of the Meeting, moved in terms of the notice of motion given by Mr. Coleman:—

"That the Society vote a sum of fourteen pounds to the 'Graham' Medal and Lecture Fund, in respect of the expenditure of that sum in advertising, and printing cards of invitation to the Members of the Society and their friends, for the Inaugural 'Graham' Lecture on 22nd January last; and, further, that it is desirable that the Society approve of the capital fund being raised to three hundred and fifty pounds, as originally intended by the Committee of the fund, in order that it may be enabled to bear the expense of the Triennial Medal and Triennial Lecture arranged by its draft constitution;" which was seconded by Mr. John Mayer, and agreed to.

The Chairman stated that, being a money vote, it would fall to be again voted on at next Meeting of the Society.

December 17, 1879.

The Philosophical Society of Glasgow met this evening at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

The following were proposed as Members of the Society, viz.:—

Mr. James F. Stark, Hebburn-on-Tyne. Recommended by Mr. James Mactear, Mr. W. R. W. Smith, and Mr. E. M. Dixon.

Mr. W. J. Chrystal, Shawfield Works, Rutherglen. Recommended by Mr. Louis Leisler, Mr. Robert R. Tatlock, and Dr. William Ramsay.

Mr. Robert Easton, Chartered Accountant, 115 Buchanan Street. Recommended by Mr. James Thomson, F.G.S., Dr. Fergus, and Dr. Stirton.

The Chairman, before proceeding with the business, made reference to the death of Mr. James R. Napier, F.R.S., since last meeting of the Society, as one of its oldest and foremost Members, and to the loss it had thereby sustained, and proposed that the Council be empowered to draw up and send a letter to Mrs. Napier, in name of the Society, expressing its sympathy with her and her family on this very great bereavement, which was unanimously agreed to; also, that one or more Members, who knew Mr. Napier well, should be appointed to draw up a memoir for insertion in the *Proceedings*, with a sketch of the work he has done. This was left to the Council to arrange.

The Chairman asked the forbearance of the Society, to hear a communication which Mr. James Mactear had to make.

Mr. Mactear said that, on the 12th of the present month, he had sent a communication to Mr. Dixon, the Secretary, giving the ascertained results of some discoveries he had made, but they were of such a startling nature that he thought it proper to have the note kept sealed until this meeting—until, in fact, he had satisfied himself by all the means in his power, and had obtained more competent opinions than his own, as to the nature of these results. Since that time he had been in London, and had shown the results to Professor Tyndall, Professor Smyth, and others, and they were now in the hands of Mr. Maskelyne, of the British Museum. They were briefly these:—After having thought carefully from time to time over the subject, and made many abortive experiments, extending over a period which dated back to 1866, he had at last succeeded in obtaining crystalline forms of carbon. They were perfectly pure and transparent, and had all the refractive power of diamonds. They had their crystalline form, and resisted acids, alkalies, and the intense heat of the blowpipe. They also scratched glass, and the only other tests that remained to be applied were as to whether they could scratch diamonds or be scratched by them, and as to the refractive index of the crystal itself and the measurement of the angle of the crystals. These tests, as he had said, had not been carried out, but they would be shortly, and he hoped to put some of the specimens before the Society on a future occasion. He had no doubt in his own mind, and neither was there any doubt in the minds of scientific gentlemen whom he had consulted, that they were diamonds, but in the meantime he preferred to describe them as a pure crystalline form of carbon. Some of the crystals he had obtained were one-thirty-second of an inch in size.

Mr. E. M. Dixon, B.Sc., Secretary, Head Master of Allan Glen's Institution, then read a paper on "The Present Position of Scientific and Technical Education in Germany." The Chairman moved a vote of thanks to the author, which was heartily accorded. Remarks or questions having been invited, Dr. Donald Morrison, Rev. Dr. Dodds, Dr. George Buchanan, Mr. John D. Campbell, and others spoke. A motion was then made by Mr. John Mayer, seconded by Mr. W. R. W. Smith, and carried unanimously, to the effect that, from the importance of the subjects embraced in the paper, and the desirableness of its being brought under the notice of those interested in technical education, the further discussion be adjourned for four weeks, and that, in the meantime, the paper, with the discussion of this evening, be printed and circulated among the Members and such other parties or educational bodies as the Council may think fit, with a view to a large attendance of Members and friends interested, on 14th January next.

In the continued absence of Mr. J. J. Coleman, F.I.C., F.C.S., from illness, the Chairman, with consent of the Meeting, moved the ratification of the following motion, made and passed at last Meeting, proceeding upon Mr. Coleman's notice, viz.:—

"That the Society vote a sum of fourteen pounds to the 'Graham' Medal and Lecture Fund, in respect of the expenditure of that sum in advertising, and printing cards of invitation to the Members of the Society and their friends, for the Inaugural 'Graham' Lecture on 22nd January last; and, further, that it is desirable that the Society approve of the capital fund being raised to three hundred and fifty pounds, as originally intended by the

Committee of the fund, in order that it may be enabled to bear the expense of the Triennial Medal and Triennial Lecture arranged by its draft Constitution;" which was seconded by Mr. Archibald Robertson, and agreed to.

It was intimated that the next Meeting of the Society would be held on 7th January.

January 7, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

The following were proposed as Members of the Society, viz.:—

Mr. Malcolm Black, M.B., C.M. Recommended by Mr. John Foulds, L.D.S., Mr. John E. Poynter, and Dr. David Foulis.

Mr. Frank Sewill, Chronometer Maker to the Admiralty, 126 Broomielaw. Recommended by Mr. G. A. Waghorn, Mr. John Mann, and Mr. E. M. Dixon.

Mr. Alex. B. Stewart, 5 Buchanan Street. Recommended by Mr. Archd. Robertson, Dr. Henry Muirhead, and Mr. John Mann.

Mr. John Snodgrass, Washington Mills, Washington Street. Recommended by Mr. John Farquhar, Mr. Archibald Robertson, and Mr. John Mann.

Mr. Robert Franklin Muirhead, B.Sc., read a paper on "A Substitute for Euclid's Third Postulate," for which the thanks of the Society were accorded.

Mr. J. B. Hannay, F.R.S.E., F.C.S., read a paper on "The Volumes of Liquid and Solid Cast-iron, with reference to the Theories of Volcanic Action," for which the Society awarded their thanks to the author; and

Dr. Henry Muirhead then read a communication from Mr. Joseph Whitley, of Leeds, in continuation of his experiments "On the Relative Specific Gravities of Solid and Melted Metals, &c., at the Temperature of Fusion," reported to the Society on 17th April, 1878. Remarks having been invited on these two papers conjoined, Dr. William Ramsay, Dr. Wallace, and Mr. Day spoke. Mr. Hannay and Dr. Muirhead replied, and the thanks of the Society were voted to Dr. Muirhead for his communication.

Dr. William Ramsay, University Laboratory, Secretary of the Chemical Section, read a paper on "Colour-Blindness," for which he received the thanks of the Society.

Mr. St. John Vincent Day made a statement with regard to the production of Crystalline forms of Carbon, by Mr. Robert S. Baxter, of Dundee, and read a paper describing the facts communicated by that gentleman to him, claiming to have produced them in 1877.

January 14, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

This Meeting being an adjournment from 17th December, for the discussion of Mr. E. M. Dixon's paper, then read, "On the Present Position of Scientific and Technical Education in Germany;" in the absence of Mr. John Mayer, the mover of the motion for adjournment, Mr. W. R. W. Smith, who seconded the motion, was called upon to open the discussion, and addressed the Meeting accordingly.

Mr. Gustav Jacoby followed, and Professor Dickson, University; Messrs. J. B. Mirrlees, W. P. Buchan, and David Rowan spoke, when Mr. Dixon read some remarks on the subject by Professor E. J. Mills, Anderson's College, who was unable to be present. Thereafter, Mr. C. C. Lindsay, C.E., Hon. Secy. of Mechanics' Institution, addressed the Meeting, followed by Mr. John L. K. Jamieson, Dr. J. R. Wolfe, Mr. David Sandeman, Mr. Thomas Muir, Vice-President; Mr. Wm. Caldwell, Mr. David Thomson, F.R.I.B.A., and others.

Mr. Dixon made a short reply.

Professor Dickson proposed a vote of thanks to the Society, from the non-members present, for its kindness in having invited them to take part in the discussion, which was carried by acclamation.

January 21, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the Meeting of the Society, held on 7th inst., having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

The following were proposed as Members of the Society, viz.:—

Mr. James Young, 12 Franklin Terrace, Dumbarton Road. Recommended by Mr. David Thomson, F.R.I.B.A., Mr. George J. Combe, and Mr. Matthew Forsyth, I.A.

Mr. Robert Murdoch, Builder, 16 Main Street, Gorbals. Recommended by Mr. David Thomson, F.R.I.B.A., Mr. A. Lindsay Miller, and Mr. Andrew Wells.

Mr. A. C. Hunter, Measurer, 197 St. Vincent Street. Recommended by Mr. David Thomson, F.R.I.B.A., Mr. George J. Combe, and Mr. Andrew Wells.

Mr. Robert Whitson, Measurer, 197 St. Vincent Street. Recommended by Mr. David Thomson, F.R.I.B.A., Mr. A. Lindsay Miller, and Mr. Matthew Forsyth, I.A.

Mr. Adam Walker, Merchant, 35 Elmbank Crescent. Recommended by Mr. Walter Easton, Mr. George Watson, and Mr. R. Cooper Rundell.

Mr. B. H. Remmers, Merchant, 63 West Regent Street. Recommended by Mr. Gustav Jacoby, Mr. Sig. Schuman, and Mr. E. M. Dixon.

Mr. Thomas Brown Henderson, M.D., 17 Elmbank Crescent. Recommended by Dr. Andw. Fergus, Dr. Henry Muirhead, and Mr. E. M. Dixon.

Professor George Forbes, B.A., F.R.S.E., of Anderson's College, read a Description of the Fire-damp Indicator by Sound, or "Damposcope," recently invented by him, and exhibited the instrument as now perfected, along with the earlier forms of it, and the apparatus employed to test its indications. The Meeting awarded its hearty thanks to the author. The reading gave rise to some remarks on the propriety of Government making its use compulsory in all mines.

Professor Forbes then proceeded to show the Experiments of Mr. Crookes, F.R.S., on Radiant Matter, with explanatory remarks, but these were unfortunately interrupted by the failure of the coil employed. Mr. Forbes was thanked for his Remarks, and kindly undertook to resume and conclude the experiments at the Society's next Meeting.

The following gentlemen, who had been balloted for, were declared duly elected, viz.:—Mr. Malcolm Black, M.B., C.M., 5 Canning Place; Mr. Frank Sewill, Chronometer Maker to the Admiralty, 126 Broomielaw; Mr. Alex. B. Stewart, 5 Buchanan Street; and Mr. John Snodgrass, Washington Mills, Washington Street.

A letter was read from Mrs. Napier, in acknowledgment of a letter of sympathy sent to her in accordance with the resolution of the Society on 17th ult. The letters are as follows, viz.:—

"PHILOSOPHICAL SOCIETY OF GLASGOW, 276 SAUCHIEHALL STREET, 14*th January*, 1880.—Mrs. Napier, Dear Madam,—In conformity with a resolution of the Philosophical Society of Glasgow, I beg to convey to you an expression of the sorrow with which the Society has heard of the decease of Mr. Jas. R. Napier, F.R.S., your late husband, and of their sympathy with you and your family in your bereavement.

"You are well aware of the interest which Mr. Napier took for many years in the operations of this Society, and it will therefore be pleasing to you to know that his efforts to promote its usefulness were ever highly appreciated, and that he was universally regarded as one of its most distinguished ornaments. For many years the Society has had to thank him for contributions of great scientific value made to it from time to time, and it is also well known that his influence within the extensive circle of his literary and scientific acquaintanceship has long been the means of bringing before the Society many valuable and original contributions from his friends. It was ever felt that he had in his own mind a high idea of the dignity and value of scientific work, and that his presence in the Society tended powerfully to repress the mercenary ideas of science which are ever prone to develop themselves in a large mercantile city. The Society deplores the loss of his disinterested love of science no less than the originality and vigour of his mind, and, out of regard for his memory, it has resolved to publish in its *Proceedings* for the present Session an account of his scientific career, which has come unfortunately too soon to a close.

"You, dear Madam, and your family look upon him from a nearer and a dearer point of view than is open to any Society, however appreciative of his mental and moral worth; but I hope that this expression of the Society's regret at his loss will, inadequate although it may be, tend to strengthen in your mind the consoling thought that his life was fruitful to his fellows.—I remain, dear Madam, yours truly, (Signed) ANDREW FERGUS, *President.*"

"22 BLYTHSWOOD SQUARE, *20th January*, 1880.—Dr. Fergus, Dear Sir, will you convey to the Members of the Philosophical Society my heartfelt thanks for their very kind letter of sympathy on the death of my dear husband, Mr. James R. Napier.—Believe me, dear Sir, yours sincerely, (Signed) EMMA NAPIER."

February 4, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the Extra Meeting of the Society, held on 14th ult., and of the Ordinary Meeting, held on 21st ult., having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

The following were proposed as Members of the Society, viz.:—

Mr. M. Campbell Duff, Measurer, 115 Wellington Street. Recommended by Mr. A. Lindsay Miller, Mr. David Thomson, F.R.I.B.A., and Mr. John Mann.

Mr. James Grierson, Merchant, 4 Westbourne Gardens, Kelvinside. Recommended by Mr. James C. Wyper, Mr. William Smith, and Mr. Archd. Robertson.

Mr. W. E. Koch, B.A., F.G.S., F.C.S., Engineer, Parkhead Forge and Rolling Mills. Recommended by Dr. Foulis, Dr. Lothian, and Mr. R. H. Moore.

Mr. James Fergus, Iron Merchant, 5 Burnbank Gardens. Recommended by Mr. James M. Cherrie, Mr. H. Wallace, and Mr. John Robertson.

Professor George Forbes, B.A., F.R.S.E., of Anderson's College, repeated the experiments of Mr. Crookes, F.R.S., on Radiant Matter, which had been interrupted at the Meeting on 21st January, and accompanied them with explanatory remarks.

Mr. E. C. C. Stanford, F.C.S., characterized the beautiful experiments as having a bearing of the very highest importance in the present age, and after some observations and questions by others, Mr. Forbes was awarded a very hearty vote of thanks for having so kindly devoted two evenings to put them fully before the Society.

Dr. J. R. Wolfe, F.R.C.S.E., read "Some Remarks on the Perception of Light and Colour," illustrated by coloured diagrams, and by the perimeter, an instrument for measuring the range of sensitiveness of the human retina; and showed its application to measuring the range of colour-vision in individuals. He also referred to Dr. William Ramsay's paper, read on 7th January, on "Colour-Blindness." Dr. Wolfe received the thanks of the Society.

Mr. James Mactear, F.C.S., made a further communication on his attempts to obtain carbon in its crystalline modification, and referred to the specimens arranged in a series of microscopes for exhibition to the Members at the close of the Meeting. A vote of thanks was awarded to Mr. Mactear for his communication, and the Meeting examined the specimens with evident interest.

Mr. St. John Vincent Day, in answer to a question, stated that he was not in a position to make any further public communication at present as to the experiments on the crystallization of carbon going on in Dundee, regarding which he communicated a statement to the Society on 7th January.

The following gentlemen who had been balloted for, were declared duly elected, viz.:—Mr. James Young, 12 Franklin Terrace, Dumbarton Road; Mr. Robert Murdoch, Builder, 16 Main Street, Gorbals; Mr. A. C. Hunter, Measurer, 197 St. Vincent Street; Mr. Robert Whitson, Measurer, 197 St. Vincent Street; Mr. Adam Walker, Merchant, 35 Elmbank Crescent; Mr. B. H. Remmers, Merchant, 63 West Regent Street; Mr. Thos. Brown Henderson, M.D., 17 Elmbank Crescent.

February 18, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

The following were proposed as Members of the Society, viz. :—

Mr. R. A. M'Gilvray, Modeller and Plasterer, 65 Bath Lane, Wellington Street. Recommended by Mr. A. Lindsay Miller, Mr. David Thomson, F.R.I.B.A., and Mr. John Mann.

Mr. George Cranston, Jun., Chemist, Sydney Street. Recommended by Mr. Robert R. Tatlock, Mr. David Storer, and Mr. David Thomson, F.R.I.B.A.

Mr. John C. Brown, Merchant, 149 West George Street. Recommended by Mr. James Dickie, Mr. R. Easton, and Mr. John Mayer.

Dr. Neil Carmichael, one of the Vice-Presidents of the Biological Section, read a paper on "An Experimental Investigation into the Trap and Water-closet System, and the relation of the same to Sewage Products, gaseous and other." The paper, which was a communication from the Sanitary Section, was illustrated by diagrams, &c., and the Meeting accorded a hearty vote of thanks to the author—the Chairman noticing the great labour involved in conducting the experiments and observations, of which the results only were now submitted. Some remarks and questions followed, by Mr. Buchan, Mr. Bromhead, Dr. Wallace, and others, and Dr. Carmichael replied.

The following gentlemen, who had been balloted for, were declared duly elected, viz. :—Mr. M. Campbell Duff, Measurer, 115 Wellington Street; Mr. James Grierson, Merchant, 4 Westbourne Gardens, Kelvinside; Mr. W. E. Koch, B.A., F.G.S., F.C.S., Engineer, Parkhead Forge and Rolling Mills; and Mr. James Fergus, Iron Merchant, 5 Burnbank Gardens.

February 26, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

Isaac Shone, Esq., C.E., F.G.S., Ex-Mayor of Wrexham, who had kindly consented to come to Glasgow to read a paper, was introduced by the Chairman.

The Chairman stated that the Council had arranged to invite to this Meeting the Sanitary Authorities of the City and surrounding Burghs, and that accordingly such invitations had been issued, and he welcomed those who had responded by their presence this evening, and stated that the Meeting was an open one, and that any one might take part in discussing the subject of the paper.

Mr. Shone then read his paper "On Sewage, Sewerage, and Drainage, Scientific and Sanitary, *versus* Unscientific and Unsanitary Sewage or Drainage, with an Exposition of his new Pneumatic Sewage System." The Chairman moved a hearty vote of thanks to the author for the trouble he had taken in preparing this paper, and for his great kindness in coming so far to read it to this Meeting, which was carried by acclamation. Dr. Wallace, Mr. G. W. Muir, Mr. W. P. Buchan, Dr. Foulis, and others took part in the remarks and discussion which followed. Mr. Shone replied to the various questions.

March 3, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street.

In the absence of Dr. Andw. Fergus, President, from indisposition, Mr. James Mactear, President of the Chemical Section, was called to the Chair.

The Minutes of the Meeting of the Society on 18th, and of the Extra Meeting on 26th ult., having been printed in the notice calling this Meeting, were held as read, and were confirmed.

The Chairman read a notice of a legacy of £100 which had been received from the Trustees of the late Robert Napier, Esq., of Shandon, being a portion of the sum left by him for Scotch and English Institutions.

The Chairman read the following communication, dated Boston, Mass., U.S.A., 1st January, 1880:—"The American Academy of Arts and Sciences will celebrate its 100th Anniversary on the 26th day of May, 1880. An address will be delivered by the President of the Academy, the Honourable Charles Francis Adams, LL.D., to be followed by a reception. The Academy hopes for the presence, on this occasion, of many of its Foreign Honorary Members, as well as of its Associate Members in other parts of the United States. The company of one or more delegates from the Philosophical Society of Glasgow is respectfully invited. ROBERT C. WINTHROP, *Chairman.*" *(Followed by the names of the Centennial Committee.)*

It was agreed that the communication be printed in the Minutes, and reported on by the Council at next Meeting.

It was announced that the pamphlet on Technical Education mentioned in the last circular was now to be had at the publishers.

The following were proposed as Members of the Society, viz.:—

Mr. John Latta, Iron Merchant, 138 West George Street. Recommended by Mr. J. D. Thomson, Mr. James Dickie, and Mr. John Mann.

Mr. Henry Lamont, Steamship Owner, 30 Gordon Street. Recommended by Mr. John D. Thomson, Mr. James Dickie, and Mr. John Mann.

Mr. James Christie, A.M., M.D., Secretary of the Sanitary and Social Economy Section, read a paper on "Provident Dispensaries, as a means for promoting the Public Health," being a communication from that Section.

Dr. Glaister and Dr. Lothian took part in a discussion, and the Chairman spoke from an employers' point of view; and a hearty vote of thanks having been voted to Dr. Christie, he made a reply.

Mr. John Mayer exhibited and described the Improved Safety Lamp invented by Mr. Douglas, Edinburgh, who was present and received the thanks of the Society.

The following gentlemen, who had been balloted for, were declared duly elected, viz.:—Mr. M. Campbell Duff, Measurer, 115 Wellington Street; Mr. James Grierson, Merchant, 4 Westbonrne Gardens, Kelvinside; Mr. W. E. Koch, B.A., F.G.S., F.C.S., Engineer, Parkhead Forge and Rolling Mills; and Mr. James Fergus, Iron Merchant, 5 Burnbank Gardens.

Mr. John Mayer gave notice that, before the Minutes were signed at next Meeting, he would ask a question relative to the printing of the Society's *Proceedings.* Mr. Alexander Scott pointed out that this would be incompetent, in respect that such business could not be brought forward till 9.40 P.M.

March 17, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the Meeting of the Society on 3rd March having been printed in the notice calling this Meeting, were held as read, and were confirmed.

The following gentleman was proposed as a Member, viz.:—Mr. Thomas Falconer, Merchant, 50 Kelvingrove Street.

Dr. James Adams, F.F.P.S.E., read a paper "On Improvements in Gas Stoves." Dr. Wallace, Professor Dittmar, Mr. W. P. Buchan, Mr. John Mayer, Mr. John Hay, and others, took part in a discussion, and a hearty vote of thanks having been voted to Dr. Adams, he replied.

The following gentlemen, who had been balloted for, were declared duly elected, viz.:—Mr. John Latta, Iron Merchant, 138 West George Street, and Mr. Henry Lamont, Steamship Owner, 30 Gordon Street.

The President drew attention to the notice of the Centennial Meeting of the American Academy of Arts and Sciences, which appeared in the circular calling this Meeting, and stated that the Council would be glad to know of any Member of the Society going to America about that time, in order that arrangements might be made for the representation of the Society.

Mr. Mayer asked for information as to why a paper, read early in the present Session before the Chemical Section, by Mr. J. B. Hannay, had not appeared in the recent issue of the Society's *Proceedings*. The Secretary explained that the letter sent to him by the Secretary of the Chemical Section in connection with that paper had been duly laid before the Council—that the Council did not find in the letter any recommendation from the Section that the paper should be printed—that this fact had been communicated, in accordance with the instructions of the Council, to the Secretary of the Chemical Section—and that no reply had since been received.

March 31, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

The following gentleman was proposed as a Member, viz.:—Mr. Jas. Johnston Dobbie, M.A., D.Sc., Assistant to the Professor of Chemistry, University. Recommended by Professor Ferguson, Mr. Jas. Mactear, and Mr. Jas. B. Hannay.

Mr. Horatio K. Bromhead, A.R.I.B.A., one of the Vice-Presidents of the Sanitary Section, read a paper "On the Ventilation of the Rooms of Houses, with Experiments," being a communication from that Section. An animated and lengthened discussion took place, in which the following gentlemen took part, viz.:—Mr. W. P. Buchan, Mr. Alex. Scott, Mr. D. G. Hoey, Dr. Eben. Duncan, Dr. Wallace, Mr. W. R. W. Smith, Mr. D. M. Nelson, Mr. John Mayer, Mr. John Hay, and the Chairman. Mr. Bromhead replied, and a hearty vote of thanks was accorded to him.

The following gentleman, who had been balloted for, was declared duly elected, viz.:—Mr. Thomas Falconer, Merchant, 50 Kelvingrove Street.

April 14, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

Mr. John Glaister, M.B., L.R.C.S. Ed., etc., read a paper on "The Physiology of Sleep," being a communication from the Biological Section, for which he received the thanks of the Society. Several Members took part in the discussion of the paper, including Dr. Robert Renfrew, Mr. A. Scott, Dr. W. J. Fleming, and the Chairman; and Dr. Glaister replied.

Mr. James Thomson, F.G.S., one of the Vice-Presidents of the Biological Section, read a paper "On Corals," being also a communication from that Section; and exhibited illustrative plates of his recent researches. The thanks of the Society were awarded to the author.

The following gentleman, who had been balloted for, was declared duly elected, viz.:—Mr. Jas. Johnston Dobbie, M.A., D.Sc., Assistant to the Professor of Chemistry, University.

April 28, 1880.

The Philosophical Society of Glasgow met this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Andw. Fergus, President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed, and signed by the Chairman.

Dr. Jas. B. Russell, B.A., Medical Officer of Health for the City of Glasgow, and President of the Sanitary and Social Economy Section, read a paper on "The Conveyance of the Contagium of Anthrax to Hair Factory Workers, as illustrative of the Particulate Theory of the Contagia," being a communication from that Section, for which he received the cordial thanks of the Society. The paper elicited several questions, and a discussion, in which Dr. Andrew Buchanan, Mr. Long, Mr. Kirsop, Mr. Scott, Mr. W. R. W. Smith, Dr. H. C. Cameron, Dr. Gairdner, Mr. Mayer, and the President took part. Dr. Russell replied.

The reading of a communication from Dr. R. Angus Smith, F.R.S., F.C.S., Manchester, Honorary Member of the Society, "On the Mud of the Frith of Clyde," was postponed till next Meeting.

Reports of the proceedings of the Sections during the Session were given in by their respective Secretaries, viz.:—Architectural Section by Mr. A. Lindsay Miller; Biological Section, by Dr. D. C. M'Vail; Chemical Section, by Dr. J. J. Dobbie; and Sanitary and Social Economy Section, by Dr. Jas. Christie; but, owing to the lateness of the hour, were held as read, and ordered to be printed in the *Proceedings.*

Dr. William Wallace stated that he was prepared to make a motion on behalf of the Council, but since it might be regarded as a money vote, he proposed that the rule as to notice of motion be suspended, in order that it might be considered at this Meeting, and thus expedite the business by requiring only one other Meeting to confirm it instead of two, and he moved accordingly; which was seconded by Mr. John Mayer, and unanimously agreed to. Thereupon Dr. Wallace moved "That—in the event of the Exhibition Fund of 1847, now in the hands of the Corporation, being made available as a Guarantee—the Society approve of the Council taking all necessary steps for holding an Exhibition of Gas Apparatus, &c., in the autumn," which was carried unanimously.

Dr. Wallace explained that this subject had been before the Council for some months, and that the scope of the proposed Exhibition, in order to make it interesting and useful, was intended to embrace apparatus relating (1) to the *manufacture* of coal Gas, its storage, distribution, and measurement; the regulation of pressure and quantity, and the photometric testing of quality; (2) to its *uses* in lighting, heating, cooking, ventilating, and as a motive power in engines of various kinds; (3) the products of gas manufacture, as tar, dyes, ammonia salts, &c.; (4) candles, paraffin, and other oils as light producers, gasoline machines for producing gas from oils, &c.; (5) electric lighting, and engines, electric and telephonic communication; (6) water measurement and regulation, hydraulic engines, &c.

The Chairman intimated that an Extra Meeting of the Society would be held on 5th May, to confirm Dr. Wallace's motion, when Dr. Angus Smith's paper would be read.

The following gentlemen were proposed as Members of the Society, viz.:—

Mr. James Young, Jun., Kelly, Wemyss Bay. Recommended by Sir Wm. Thomson, Professor James Thomson, LL.D., F.R.S., and Professor Ferguson.

Mr. Alex. S. Wilson, M.A., B.Sc., Professor of Botany, Anderson's College. Recommended by Dr. Henry Muirhead, Mr. Archd. Robertson, and Mr. John Mann.

Mr. Alexander W. Donald, Colliery Salesman, Bank Place, Cambuslang. Recommended by Dr. Henry Muirhead, Mr. Archd. Robertson, and Mr. John Mann.

Mr. John Fowler, Builder, Kelvinbank Terrace, 4 Gray Street, Sandyford. Recommended by Dr. Henry Muirhead, Mr. Archd. Robertson, and Mr. John Mann.

Mr. Hugh Reid, Engineer, 10 Woodside Terrace. Recommended by Dr. Fergus, Dr. Henry Muirhead, and Mr. E. M. Dixon.

Mr. James Reid, Jun., Engineer, 10 Woodside Terrace. Recommended by Dr. Fergus, Dr. Henry Muirhead, and Mr. E. M. Dixon.

Mr. John Sutherland, Greenbrae, Pollokshields. Recommended by Dr. Fergus, Dr. Henry Muirhead, and Mr. John Mann.

Mr. David Sutherland, Jun., Greenbrae, Pollokshields. Recommended by Dr. Fergus, Dr. Henry Muirhead, and Mr. John Mann.

REPORT OF THE ARCHITECTURAL SECTION OF THE PHILOSOPHICAL SOCIETY, FOR SESSION 1879-80.

The severe illness of our late Secretary at the beginning of the Session prevented arrangements being made for opening the Section. In December he sent in his resignation, and on the appointment of a new Secretary, a start was made.

Owing to this delay, it was late in January before the Section was opened, but since that it has been fairly successful. The papers read and addresses delivered were as follows—

January 28, 1880.—David Thomson, Esq., F.R.I.B.A., President of the Section, delivered his opening Address, the subject being "Our Section, its aims and objects."

February 11, 1880.—Mr. T. L. Watson read a paper on the "Acoustics of Public Buildings."

February 25, 1880.—Mr. Henry Stewart read a very interesting paper, the subject being "Wood."

March 10, 1880.—Mr. Eglin read a paper on, and exhibited specimens of, "Several American Inventions in Spring Butts, Air Springs, &c., and Wood and Paper Veneering for Interior Decorations." Afterwards the adjourned discussion on Mr. T. L. Watson's paper, "Acoustics of Public Buildings," was opened by the President, Mr. Thomson.

March 24, 1880.—Thomas Bonar, Esq., of Edinburgh, read a paper on "Interior Colouring worthy the study of the Architect."

The thanks of the Section are due to all these gentlemen.

We regret to state that shortly after sending in his resignation, Mr. Matthew Forsyth died. By his death the Section sustained a severe loss, as his energy and ability did much to make the Section a success.

The Section has increased its numbers by admitting 25 associates during the Session.—A. LINDSAY MILLER, *Hon. Secretary of Section.*

REPORT OF THE BIOLOGICAL SECTION OF THE PHILOSOPHICAL SOCIETY, FOR SESSION 1879-80.

A paper was read by Dr. John Glaister, on the "Physiology of Sleep," and one by Mr. James Thomson, F.G.S., on a "New Genus of Corals."—D. C. M'VAIL, *Secretary of Section.*

REPORT OF THE CHEMICAL SECTION OF THE PHILOSOPHICAL SOCIETY, FOR SESSION 1879-80.

During Session 1879-80 this Section held nine General Meetings. A large number of interesting papers were brought before the Section, and the reading of several of these, especially of the papers relating to Applied Chemistry, was followed by a valuable discussion.

The following is a list of the papers read:—

November 24, 1879.—Mr. J. B. Hannay: "On Crystalline Cavities."

December 8, 1879.—President's Address: "On the Antiquity of Chemical Science."

December 22, 1879.—Dr. W. Ramsay: "On some relations between Heat and Expansion."

February 9, 1880.—(1) Communicated by the Secretary: "Note on Garnets from Maryhill," by Mr. J. J. Hammell. (2) Mr. Alex. Wilson: "Chemistry of a Pea Pod."

February 23, 1880.—Professor Ferguson: "The Life of Jean Beguin."

March 8, 1880.—Communicated by Mr. Snodgrass: "The Rise of Bulbs in Liquids," by Dr. Mills.

March 22, 1880.—Dr. J. R. M. Robertson: "Sarawak, Borneo, and its Ores of Antimony, Arsenic, and Mercury."

April 5, 1880.—(1) Dr. Wallace: "On the condition in which Sulphur exists in Coal." (2) Dr. Wallace: "On a Peculiar Water." (3) Mr. Tatlock: "On the Pellets occasionally found in Pig and Foundry Iron."

April 19, 1880.—(1) Mr. Mactear: "On some curious Specimens of Monohydrated Crystals of Carbonate of Soda." (2) Mr. Mactear: "On some recent Investigations on the Source of Sulphuretted Hydrogen in Mineral Water," translated from the French of M. Eugène Plancherd. (3) Mr. Mactear: "On the Action of Concentrated Sulphuric Acid on various qualities of Lead."

Of the 14 papers enumerated above, 2 are on historical chemistry; 2 on physical chemistry; 1 on vegetable chemistry; 3 on mineral chemistry; 3 on applied chemistry; and 3 on miscellaneous subjects.

Four papers were recommended to the Philosophical Society for publication.

During the Session 4 new associates were admitted to the Section.—JAMES JOHNSTON DOBBIE, *Secretary of Section.*

REPORT OF THE SANITARY AND SOCIAL ECONOMY SECTION OF THE PHILOSOPHICAL SOCIETY FOR 1879-80.

At a Meeting of the Sanitary and Social Economy Section, held at the opening of the Session, 1879-80, the following Office-bearers were elected:—

President.—Dr. J. B. Russell.

Vice-Presidents.—Messrs. John Ure and H. K. Bromhead.

Other Members of Council.—Mr. S. Schuman, Mr. P. W. Dixon, Mr. W. P. Buchan, Mr. A. Scott, Mr. W. R. W. Smith, Dr. R. Renfrew, Mr. K. M. Macleod, Mr. E. C. C. Stanford, Mr. A. Frew, Mr. D. Sutherland, Mr. A. Hewat, Dr. E. Duncan.

Secretary.—Dr. James Christie.

The following papers from the Section were read during the Session before General Meetings of the Society, viz.:—"On Disinfection by Acids," by John Dougall, M.D., Lecturer on Materia Medica, Glasgow Royal Infirmary (3rd November, 1879); "An Experimental Investigation into the Trap and Water-closet System, and the Relation of the same to Sewage Products, Gaseous, and Other," by Neil Carmichael, M.D., Vice-President of the Biological Section (18th February, 1880); "On Provident Dispensaries as a means for Promoting the Public Health," by James Christie, A.M., M.D., Lecturer on Hygiene and Public Health, Anderson's College (3rd March, 1880); "On the Ventilation of the Rooms of Houses," by Horatio K. Bromhead, A.R.I.B.A., Vice-President of the Sanitary Section (31st March, 1880).

A paper was also read before a Special Meeting of the Society, on February 26, 1880, by Mr. Isaac Shone, C.E., F.G.S., Ex-Mayor of Wrexham, "On Sewage, Sewerage, and Drainage, Scientific and Sanitary, *versus* Unscientific and Unsanitary Sewage and Drainage, with an Exposition of the new Pneumatic Sewage System."

On the 28th April, 1880, a paper "On the Conveyance of the Contagium of Anthrax to Hair Factory Workers, as illustrative of the Particulate Theory of the Contagia," was read by Dr. James B. Russell, B.A., Medical Officer of Health for the City of Glasgow, President of the Sanitary and Social Economy Section.

At the last Meeting of the Section, held on 14th April, the following extract was ordered to be inserted in the Report:—"The Committee appointed by the Council of the Sanitary Section, on May 15th, 1878, to draw up a statement to form the basis of representation to other public bodies in Scotland, with a view to secure co-operation in approaching Government anent the Amendment of the Public Health Act (Scotland), 1867, not having seen its way to take any action in the matter, it was proposed by Mr. W. R. W. Smith, and unanimously agreed to, that the Society be requested to grant a continuance of the power granted to the Sanitary Section, and recorded in the Minutes of the Society's Meeting of April 5th, 1878, viz.:—'That the Sanitary Section of this Society be authorised to take measures towards the Amendment of the Health of Scotland Act (1867).'"—JAMES CHRISTIE, A.M., M.D., *Secretary.*

May 5, 1880.

The Philosophical Society of Glasgow held an Extra Meeting this evening, at eight o'clock, in the West Hall of the Upper Galleries, Corporation Buildings, Sauchiehall Street. Dr. Henry Muirhead, Vice-President, in the Chair.

The Minutes of the last Meeting of the Society having been printed in the notice calling this Meeting, were held as read, and were confirmed, and signed by the Chairman.

A communication from Dr. R. Angus Smith, F.R.S., F.C.S., Manchester, Honorary Member of the Society, which had been postponed from last Meeting—"On the Mud of the Frith of Clyde"—was read by Mr. E. M. Dixon, the Secretary. Mr. John Kirsop, Mr. Scott, Mr. John Mayer, Dr. Wallace, Dr. Stirton, Mr. Alex. Scott, Mr. Jas. Thomson, and Mr. W. R. W. Smith, severally made remarks on the subject of the Paper. The thanks of the Society were heartily accorded to Dr. Smith for his communication, and the Secretary was instructed to write to this effect.

The Chairman having declared that the quorum of thirty required by the Rules to constitute a Business Meeting at this period of the year was much exceeded by the present attendance (upwards of 40 Members being present), Dr. William Wallace, on behalf of the Council, moved, for the second time, "That—in the event of the Exhibition Fund of 1847, now in the hands of the Corporation, being made available as a Guarantee—the Society approve of the Council taking all necessary steps for holding an Exhibition of Gas Apparatus, &c., in the autumn;" which was seconded by Mr. John Mayer, and unanimously agreed to.

The thanks of the Society were voted by acclamation to Dr. Fergus for the manner in which he has discharged the duties of the presidency during the Session.

Minute of Extraordinary Meeting of the PHILOSOPHICAL SOCIETY OF GLASGOW, held within the RELIGIOUS INSTITUTION ROOMS, No. 172 Buchanan Street, on Thursday, the 17th day of June, 1880, at two o'clock p.m.

PRESENT—

Sir W. Thomson,
Prof. James Thomson,
Drs. Andw. Fergus,
W. T. Gairdner,
D. C. M'Vail,
Hugh Thomson,
Messrs. Sig. Schuman,
Wm. Gorman,
H. R. Robson,
Archd. Robertson,
James Young,
James Young, Jun.,
W. P. Buchan,
A. Hewat,
James Mactear,
Alexr. Whitelaw,
Wm. Galbraith,
Messrs. G. W. Clark,
John S. Dunn,
E. C. C. Stanford,
John L. K. Jamieson,
John Kirsop,
Robert Gray,
John Mayer,
Wm. Henderson,
Wm. Ramsay,
David Thomson,
John Muir,
James Howatt,
James Murdoch,
William Ker,
James Downie,
George Watson,
James Smith.
John Mann, *Treasurer.*

Dr. Andw. Fergus, M.R.C.S., Eng., *President*, in the Chair.

The notice calling the Meeting having been read by Mr. Mann, as Assistant-Secretary, the Chairman explained that the Council had authorised this special meeting to be called, owing to the extreme desirableness of the Society supporting the Bill in question—"The Bill to amend the Law relating to Patents for Inventions, 1880"—that such support would be quite on the lines of the previous petitions from the Society—that the Council had further authorised him as President to petition or memorialize, as might be thought best, in name of the Council, should the urgency of the case have required it, before this Meeting could be held; and he then called upon Sir William Thomson to make a statement.

Sir William Thomson explained at some length the position of the Patent Laws, and said that the second reading of the Bill might come on at any time.

A Draft of a proposed Petition to the House of Commons in favour of the Bill was then read to the Meeting.

Mr. James Young of Kelly moved that the Petition as it stands, be adopted by the Society, which was seconded by Mr. James Mactear, and carried unanimously.

The President and Assistant-Secretary were authorised to sign the Petition on behalf of the Society, and to affix the Society's seal thereto.

Sir William Thomson proposed that the sanction of the Society be given to the printing and circulation of the Petition, provided the expense does not fall upon the Society, which was seconded by Mr. Wm. Henderson, and agreed to.

It was agreed that Dr. Cameron, M.P., be requested to present the Petition to the House.

A vote of thanks to Sir William Thomson for his statement, and to the Chairman, concluded the proceedings.

UNTO THE HONOURABLE

THE COMMONS OF THE UNITED KINGDOM OF GREAT BRITAIN AND IRELAND, IN PARLIAMENT ASSEMBLED.

THE HUMBLE PETITION OF THE PHILOSOPHICAL SOCIETY OF GLASGOW,

HUMBLY SHEWETH,

That the Philosophical Society of Glasgow—instituted 1802 and incorporated in 1879, consisting of nearly seven hundred members, being persons engaged in the Arts, Manufactures, Trade, and Commerce of the City—have considered the Bill brought before your Honourable House by Mr. George Anderson, Mr. Alexander Brown, Mr. Hinde Palmer, and Mr. Broadhurst, entitled "A Bill to Amend the Law relating to Patents for Inventions."

That this Bill—by making provision for the appointment of three Paid Commissioners to manage the business of the Patent Office, by providing for the reduction of the present excessive Stamp Duties payable on the obtainment of Patents, by deferring the payment of the periodic Taxes until later periods, and reducing their amounts, by extending the duration of Patents to twenty-one years, and by providing for the protection of subsequent Improvements on Patented Inventions on payment of one-half of the Stamp Duties levied on the original Patents—will remove many of the grievances felt in the working of the present Patent Law, and will be the means of greatly developing the inventive genius and energy of the people, and enabling great numbers to obtain Patents who have not heretofore had an incentive to divulge and to work out to maturity their inventions; and will thereby promote our industries and the improvement of the appliances required in the Arts and Manufactures, and in the utilization of the resources of the country, and thus prove most beneficial to all classes of the people. If passed into law, your Petitioners believe this Bill would really settle Patent legislation for many years to come.

Your Petitioners therefore humbly pray your Honourable House that the Bill may be passed into law this Session.

And your Petitioners, as in duty bound, will ever pray, &c.

Signed, in name and on behalf of the Members of
the Philosophical Society of Glasgow, by

L. S.

AND. FERGUS, *President.*
JNO. MANN, *Assistant-Secretary.*

OFFICE-BEARERS
OF THE
PHILOSOPHICAL SOCIETY OF GLASGOW.

SESSION 1879-80.

Dr. Andrew Fergus, M.R.C.S.Eng., *President.*

Dr. Andrew Buchanan,
Dr. Henry Muirhead,
Mr. Thos. Muir, M.A., F.R.S.E.,
Vice-Presidents.

Dr. Allen Thomson, LL.D., F.R.S.,
Professor Grant, M.A., LL.D., F.R.S.,
Prof. Sir Wm. Thomson, LL.D., D.C.L., F.R.S.,
Honorary Vice-Presidents.

Mr. John Robertson, *Librarian.*
Mr. John Mann, C.A., *Treasurer.*
Mr. E. M. Dixon, B.Sc., *Secretary.*

Mr. David Thomson, I.A., F.R.I.B.A., *Architectural Section,*
Dr. James Stirton, F.L.S., *Biological Section,*
Mr. James Mactear, F.C.S., *Chemical Section,*
Dr. Jas. B. Russell, B.A., *Sanitary and Social Economy Section,*
Presidents of Sections.

Other Members of Council.

Mr. Alex. Scott.
Mr. W. R. W. Smith.
Prof. John G. M'Kendrick, M.D., C.M., F.R.C.P.Ed., F.R.S.Ed.
Mr. J. Honeyman, I.A., F.R.I.B.A.
Mr. Archd. Robertson.
Mr. J. J. Coleman, F.I.C., F.C.S.
Professor D. C. M'Vail, M.B.
Mr. John Kirsop.
Dr. Wm. Wallace, F.R.S.E., F.I.C., F.C.S.
Mr. Michael Connal.
Mr. John Jex Long.
Dr. Eben. Watson, M.A.

COMMITTEES APPOINTED BY THE COUNCIL.

COMMITTEE ON FINANCE.

Dr. A. Fergus, *President.*

Mr. Archd. Robertson.
Mr. J. J. Coleman.
Mr. John Kirsop.
Dr. Wm. Wallace.
Mr. Michael Connal.
Mr. John Jex Long.

Mr. John Mann, *Treasurer, Convener.*
Mr. W. R. W. Smith, *Sub-Convener.*

COMMITTEE ON PAPERS.

Dr. A. Fergus, *President.*

Dr. Henry Muirhead,
Mr. Thomas Muir,
Vice-Presidents.

Mr. David Thomson.
Dr. James Stirton.
Mr. Jas. Mactear.
Dr. J. B. Russell.
Dr. M'Kendrick.
Mr. John Honeyman.
Prof. D. C. M'Vail.
Dr. Wm. Wallace.
Mr. Michael Connal.
Mr. John Jex Long.
Dr. Eben. Watson.

Mr. E. M. Dixon, *Convener.*

COMMITTEE ON THE LIBRARY.

Dr. Andrew Fergus, *President.*

Dr. A. Buchanan,
Dr. Henry Muirhead,
Mr. Thomas Muir,
Vice-Presidents.

Dr. James Stirton.
Mr. James Mactear.
Dr. J. B. Russell.
Mr. Alex. Scott.
Mr. J. J. Coleman.
Prof. D. C. M'Vail.
Mr. John Kirsop.

Mr. John Robertson, *Librarian, Convener.*

COMMITTEE ON BUILDING AND ACCOMMODATION;

Acting jointly with the Council of the Institute of Engineers and Shipbuilders in Scotland.

Dr. A. Fergus, *President.*

Dr. H. Muirhead,
Mr. Thomas Muir,
Vice-Presidents.

Mr. David Thomson.
Dr. J. B. Russell.
Mr. W. R. W. Smith.
Mr. John Honeyman.
Mr. Archd. Robertson.
Mr. J. J. Coleman.
Mr. John Mann.
Mr. E. M. Dixon.
Mr. John Kirsop.
Dr. Wm. Wallace.
Mr. John Jex Long.
Mr. John Robertson.

OFFICE-BEARERS OF SECTIONS.

ARCHITECTURAL SECTION.

MR. DAVID THOMSON, I.A., F.R.I.B.A., *President.*

MR. JAMES SELLARS, I.A.,
MR. ANDREW WELLS,
} *Vice-Presidents.*

MR. JAMES HOWATT, *Hon. Treasurer.*

MR. A. LINDSAY MILLER, *Hon. Secretary,*
121 West Regent Street.

Other Members of Council.

MR. J. HONEYMAN, I.A., F.R.I.B.A.
MR. JOHN COWAN.
MR. JAMES THOMSON, I.A., 81 St. Vincent Street.
MR. J. L. COWAN, I.A.
MR. GEORGE J. COMBE.
MR. STEPHEN ADAM.
MR. WILLIAM LANDLESS.
MR. CAMPBELL DOUGLAS, I.A.

BIOLOGICAL SECTION.

DR. JAMES STIRTON, F.L.S., *President.*

MR. JAMES THOMSON, F.G.S.,
MR. JOHN ROBERTSON,
DR. NEIL CARMICHAEL,
} *Vice Presidents.*

PROF. D. C. M'VAIL, M.B., *Secretary,* 400 Great Western Road.

Other Members of Council.

DR. JOSEPH COATS.
DR. JOHN DOUGALL.
MR. H. E. CLARKE, M.R.C.S.
DR. JAMES FINLAYSON.
MR. JOHN KIRSOP.
MR. ARCHIBALD ROBERTSON.
DR. HENRY MUIRHEAD.
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OBITUARY NOTICE.

JAMES R. NAPIER, F.R.S.

During the present Session the Society has suffered a very great loss by the death of one of its oldest and most active members, Mr. James R. Napier. Perhaps it is not too much to say that, taking all things into consideration—the lengthened unselfish interest he showed in its welfare, the number and importance of the papers he contributed to its *Proceedings*, the valuable communications by others which his industry and influence succeeded in bringing before it—Mr. Napier latterly stood almost alone in the Society. His well-known figure therefore cannot but be long and kindly remembered by his fellow members.

James R. Napier, born in 1821, was the eldest son of a distinguished father, Mr. Robert Napier of Shandon, whose name is so inseparably connected with the history of marine engineering and naval architecture on the Clyde. Along with his brother John, he received his early education in the High School of Glasgow, where, under Dr. Connell, he learned mathematics and natural philosophy, and gained his first successes as a student of these subjects. In later years he was wont to say that at that time the foundation of all his future work was laid, and he would show his friends with pride and gratitude a bound manuscript volume of his class exercises, in which the mathematician could not fail to perceive traces of that originality which was so marked a feature in his after character. As he was intended for his father's profession, the University as then existing could not offer him many advantages, so that after leaving the High School he spent but a comparatively short time at College, studying his favourite subjects under Professor Meikleham and Professor James Thomson, Sir William Thomson's father. Immediately thereafter he entered his father's engineering works, and there soon began boldly and vigorously to apply his theoretical knowledge and to test its value by the results of practice. Fortunately he found in the manager of the works, Mr. David Elder, one in every way suited to encourage and assist in the development of his genius. Like many other Clyde engineers he always bore in kindly remembrance his indebtedness to Mr.

Elder, and when the old man died in 1866 Mr. Napier drew up an excellent memoir of him, moved thereto, as he said, "by respect for his memory, and the great benefits received from his advice and experience." Engineering, however, was no longer to be the sole business of the firm. Since about the time of the birth of his eldest son, Mr. Robert Napier had been devoting his attention more and more to the construction of marine engines, and latterly had taken to contracting for steam vessels in their entirety, the hulls being supplied to him by Mr. John Wood, Mr. Robert Duncan, and other eminent shipbuilders. It was now, in 1842, resolved to make iron shipbuilding part of his own work, and a yard was opened at Govan for this purpose. The first ship, the "Vanguard," was built under Mr. Elder's superintendence, but shortly after the head of the firm decided to make this his eldest son's department, and thus Mr. James R. Napier's course in life was fixed. The position could not possibly be an easy one to the "inexperienced youth," as he afterwards called himself, and as he in a strict sense undoubtedly was. With characteristic determination and unbending will, however, he undertook the work of overcoming difficulties. Where experience failed him he would boldly strike out a path for himself; where a new thing had to be done he would be in perpetual unrest until he had found out a way to do it. It may be doubted whether in the business of practical naval architecture he had found his proper sphere of action: certain it is, however, that the powers of investigation which he soon showed in his written papers would have ensured success on the scientific side of any undertaking with which he might have chanced to be connected. The record of his intellectual life during the years he was engaged in shipbuilding is but a record of problems set to himself, experiments and reasoning brought to bear on their solution, and an imperious energy seeking to carry out in practice the results when obtained. Some of this work can be known and appreciated from his published writings, but of a great portion the only memorial left is to be found in the vessels which were designed and built under his charge. As an instance of these there may be mentioned the "Persia," the first *iron* vessel launched for the Cunard line, and which by its conduct in an unforeseen experiment—collision with an iceberg in the Atlantic—attested to Mr. Napier's powers of design and execution. The "Persia," however, was among the last of the steamships bearing evidence of his skill which came from the yard of Robert Napier & Sons. A year or two after he ceased to be a member of the firm and started business for himself. From the new yard a number of steamers—the "Admiral" (1858), the "Athanasian," the "Lancefield," &c. were launched, embodying ideas he had recently arrived at in conjunction with his friend Professor Rankine. These vessels achieved a marked success, and abundant verification was obtained of the importance of the theory in accordance with which they had been designed. Notwithstanding this success, the business was not developed, and by-and-by was given up. Somewhat later still Mr. Napier entirely withdrew his mind from interest in his former pursuit and led a life of retirement, devoting himself, as far as the state of his health would permit, to scientific inquiry, chiefly in connection with matters of importance in every-day life.

Mr. Napier joined the Philosophical Society as early as the year 1850; he became a life member of the British Association on the occasion of its first meeting in Glasgow in 1855; he joined the Institution of Engineers and Shipbuilders in Scotland at its foundation in 1857; for a time he was a member of the Institution of Naval Architects, and he attained the much-coveted honour of the Fellowship of the Royal Society of London in 1867.

His papers are not widely scattered, being mainly confined to the publications of the first two of these bodies. On this account the somewhat lengthy list need not be given in full. We have in 1853 "Experiments on the Evaporation of Water in Copper, Iron, and Lead Vessels;" in 1854 and 1872 important papers on the Measurement of the Speed of Ships; in 1855 on Ships' Compasses; in 1860 on Incrustations in Marine Boilers; in 1862 on Sections of least Resistance for Ships of limited breadth and limited draft of water; in 1865 on the most profitable Speed for a fully laden Cargo Steamer; in 1872 on British Weights and Measures. Up till almost the present year he continued to contribute to our Society short papers on the subjects which from time to time occupied his leisure,—the heating and ventilation of rooms, the effect of water on cooking-vessels, &c.

Mr. Napier possessed all the characteristics of the true man of science. He had the rightly doubting mind, the inquiring spirit, an almost limitless faith in scientific method, and a grip that was unyielding when he thought he had laid hold on the truth. He was original and unconventional; the words which he used in regard to Mr. Elder may be applied to their writer with even greater force

—"He thought for himself, he did not do as other people did if he could do a better thing, or even something as good, of his own." Of late years his health in every way had been far from robust; but even in these years new acquaintances could not fail to be struck with his mental power and force of character, and few of them who came to know him better and to understand him, but experienced his warmth of heart.

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Proceedings of the American Association for the Advancement of Science. 1877-78.

Transactions of the Royal Society of Edinburgh. Vols. XXVIII., XXIX., 1.

L'Année Scientifique et Industrielle. 1879.

Précis de Chimie Industrielle. By A. Payen. Vol. II.

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Journal of the Society of Arts.
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FORTNIGHTLY.

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Bulletin de la Société Chimique.
Journal für Praktische Chemie.
Polytechnisches Journal.
Telegraphic Journal.

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Annales de Chimie et de Physique.
Annals des Ponts et des Chaussées.
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Annals and Magazine of Natural History.
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Journal de Pharmacie et de Chimie.
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Journal of the Chemical Society.
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Midland Naturalist.
Monatsbericht der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
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Odontological Society's Transactions.
Proceedings of Royal Geographical Society.
Royal Astronomical Society's Monthly Notices.
Sanitary Journal.
Zoologist.

QUARTERLY.

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Bulletin de la Société Industrielle de Mulhouse.
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Popular Science Review.
Quarterly Journal of Geological Society.
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Barr, T. M., C.E., Caledonian Railway, Perth Station. 1869
Bayne, A. Malloch, 32 India street. 1878
Bell, Dugald, 47 Lansdowne cres. 1871
30 Bell, George, F.R.I.B.A., 212 St. Vincent st. 1870
Bell, Henry, 446 Camden road, London, N. 1876
Bell, James, 41 Mitchell street. 1843
Bell, James, 172 Argyle street. 1877
Bell, Robt., M.D., F.F.P.S.G. and Ed., 29 Lynedoch street. 1869
35 Beveridge, James, 81 Gloucester st. 1877
Binnie, J., 69 Bath street. 1877
Bird, Gregory, 8 Berkeley terrace. 1866
Black, D. Campbell, M.D., M.R.C.S.E., 50 Woodlands road. 1872
Black, J. Albert, 7 Newton place. 1869
40 Black, John, 16 Park terrace. 1869
Black, Malcolm, M.B., C.M., 5 Canning place. 1880
Blackie, Robert, 17 Stanhope street. 1847
Blackie, W. G., Ph.D., F.R.G.S., 17 Stanhope street. 1841
Blair, G. M'Lellan, 2 Lilybank ter. 1869
45 Blair, J. M'Lellan, 8 Cecil pl., Paisley road. 1869
Bost, Timothy, 33 Renfield street. 1876
Boucher, J., I.A., 247 St. Vincent street. 1870
Bowie, Campbell T., 26 Bothwell st. 1870
Boyd, John, Shettleston Iron Works, near Glasgow. 1873
50 Boyd, Wm., Blythswood Foundry, 61 North street. 1852
Brodie, John Ewan, M.D., C.M., F.F.P.S.G., 20 Sandyford place. 1873
Bromhead, Horatio K., I. A., A.R.I.B.A., 245 St. Vincent st. 1870
Brown, James, 76 St. Vincent street. 1876
Brown, James F., 1 Annfield place, Dennistoun. 1877
55 Brown, John, 128 Hope street. 1879
Brown, John C., 149 W. George st. 1880
Brown, Nicol, 21 Hope street. 1869
Brown, Richard, Eglinton Chemical Co., 31 St. Vincent street. 1855
Brown, Robert Langton, 92 St. Vincent street. 1875
60 Brownlee, Jas., 23 Burnbank gardens. 1860
Brownlie, Jas., Victoria Saw Mills. 1877
Brownlie, John, 2 Oakley terrace. 1874
Bruce, John Inglis, 62 Robertson st. 1869
Bruce, John L., I.A., 103 West Regent st. 1873
65 Bryce, David, 129 Buchanan street. 1872
Bryden, Robt. A., F.R.I.B.A., 15 Dalhousie street. 1870
Buchan, William P., 21 Renfrew st. 1875
Buchanan, Alex. M., M.A., M.D., Professor of Anatomy in Anderson's College, 201 St. George's rd. 1876
Buchanan, Andrew, M.D., 186 Bath street, *Vice-President.* 1833
70 Buchanan, George, A.M., M.D., Professor of Clinical Surgery in the University of Glasgow, 193 Bath street. 1875
Buchanan, Geo. S., 95 Candleriggs. 1845
Buchanan, William L., 212 St. Vincent street. 1873
Burnet, John, 167 St. Vincent st., 1850
Burns, J., M.D., 15 Fitzroy place, Sauchiehall street. 1864
75 Burns, J. Cleland, Ferntower, Crieff. 1874

Cameron, Charles, M.D., LL.D., M.P., 104 Union street. 1870
Cameron, H. C., M.D., 27 Elmbank crescent. 1873
Cameron, R., 1 North Claremont st. 1873
Campbell, J. A., LL.D., M.P., 29 Ingram street. 1848
80 Campbell, John D., 5 Derby terrace, Sandyford. 1858
Carlile, Thomas, 23 West Nile st. 1851
Carlton, Charles, 141 St. Vincent st. 1870
Carmichael, Neil, M.D., C.M., 29 S. Cumberland street. 1873
Carmichael, Thomas, 9 Windsor st., New City road. 1879
85 Carrick, John, City Architect, 74 Hutcheson street. 1846
Cassels, Robert, 168 St. Vincent st. 1858
Cassells, J. P., M.D., 2 Newton ter. 1874
Cherrie, James M., Clutha cottage, Tollcross. 1879
Christie, James, A.M., M.D., F.F.P.S.G., 2 Great Kelvin terrace, Bank street, Hillhead. 1876
90 Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1868
Chrystal, W. J., Shawfield Works, Rutherglen. 1880
Church, James, 88 Renfield street. 1867
Church, Wm., Jun., 67 St. Vincent street. 1855
Clapperton, John, 5 Sandyford pl. 1874
95 *Clark, G. W., Dumbreck house, 1877
Clark, Henry E., L.R.C.S. Eng., 9 Elmbank street. 1876

Clark, John, Ph.D., F.I.C., F.C.S., 138 Bath street. 1870
Clark, John, 9 Wilton crescent. 1872
*Clark, William, Mile-end. 1876
100 Clavering, Thos., 21 St. Vincent pl. 1856
Cleland, A. B. Dick, 76 Milton st. 1871
Clinkskill, James, 1 Holland place. 1868
Clouston, Peter, 1 Park terrace. 1861
Coats, Joseph, M.D., 7 Elmbank crescent. 1873
105 *Cochran, Robert, 7 Crown circus, Dowanhill. 1877
Coghill, Wm. C., 263 Argyle street. 1873
Coleman, J. J., F.C.S., 45 West Nile street. 1869
Collins, Wm., 3 Park terrace, East. 1869
Collins, Wm., Jun., 139 Stirling rd. 1879
110 Colquhoun, Jas., 158 St. Vincent st. 1876
Colvil, John, 62 St. Vincent street. 1877
Combe, George Jones, 34 Dundas st. 1877
Combe, Wm., 22 Dundas street. 1877
Connal, Michael, Virginia buildings. 1848
115 Connell, James, 182 Crookston st. 1870
Connell, Wm., 38 St. Enoch square. 1870
Copeland, Jas., 1 Thornville terrace, Hillhead. 1869
Copland, Wm. R., M. Inst. C.E., 146 West Regent street. 1876
Coubrough, A. Sykes, Blanefield, Strathblane. 1869
120 Couper, James, Craigforth House, Stirling. 1862
Couper, James, 37 Lansdowne cres. 1878
Couper, Wm., 9 Huntly gardens, Hillhead. 1873
Cowan, J. B., M.D., Professor of Materia Medica in the University of Glasgow, 159 Bath street. 1867
Cowan, John, 12 Ure place. 1870
125 Cowan, M'Taggart, C.E., 27 Ashton terrace, Hillhead. 1876
Cranston, George, Jun., 91 Sauchiehall street. 1880
Crawford, David, Jun., Fereneze Print Works, Barrhead. 1873
Crawford, W. B., 104 West Regent street. 1872
Crawford, William C., M.A., Hobart house, Eskbank, near Edinburgh. 1869
130 Cree, Thomas S., 17 Exchange sq. 1869
Cross, David, 25 Park circus. 1850
Cumming, J. Simpson, M.D., 310 St. Vincent street. 1874
*Cuthbertson, John N., 29 Bath st. 1850

Dansken, A. B., 102 Bath street. 1877
135 *Dansken, John, 102 Bath street. 1876
Darling, Geo. E., 247 W. George st. 1870
Davidson, T., Jun., 33 Garngadhill. 1872
Day, St. John Vincent, C.E., F.R.S.E., 115 St. Vincent street. 1866
Deas, Jas., C.E., 7 Crown gardens, Dowanhill. 1869
140 Dempster, John, 33 Abbotsford pl. 1875
Dennison, Wm., C.E., Land Surveyor, 175 Hope street. 1876
Dewar, Duncan, Kirkhill, Cambuslang. 1877
Dickie, James, 7 Claremont terrace. 1879
Dickson, James, 15 Binnie place. 1871
145 Dittmar, W., F.R.S.E., Professor of Chemistry, Anderson's College. 1875
Dixon, A. Dow, 10 Montgomerie crescent, Hillhead. 1873
Dixon, Edward M., B.Sc., 11 Hopeton place, *Secretary*. 1860
Dixon, Joseph Anthony, 175 West George street. 1870
Dixon, Peter W., 19 Elmbank cres. 1871
150 Dobbie, James Johnston, M.A., D.Sc., Assistant to the Professor of Chemistry, University, 292 St. Vincent street. 1880
Dodds, Rev. Jas., D.D., 15 Sandyford place. 1876
Donald, John, Thomson street Public School. 1872
Donald, William J. A., 29 St. Vincent place. 1877
Dougall, Franc Gibb, 167 Canning st. 1875
155 Dougall, John, M.D., F.F.P.S., Lecturer on Materia Medica in the Glasgow Royal Infirmary School of Medicine, 6 Belmar terrace, Shields road, Pollokshields. 1876
Douglas, Campbell, I.A., 266 St. Vincent street. 1870
Douie, Robert, 37 Bath street. 1869
Downie, James, North Bank house, Kirkintilloch. 1872
Downie, Robert, Jun., Carntyne Dye-works, Parkhead. 1872
160 Drew, Alex., 149 West George st. 1869
Dron, William, Cranstonhill. 1873
Dryburgh, Jas. N., 7 Matilda ter., Strathbungo, 1872
Duff, M. Campbell, 115 Wellington st. 1880
Duncan, Alex., B.A., 242 St. Vincent street. 1878
165 Duncan, Eben., M.D., C.M., F.F.P.S.G., 4 Royal crescent, Crosshill. 1873
Duncan, Robert, Engineer, Partick Foundry. 1875
*Dunlop, Nathaniel, 1 Montgomerie crescent, Great Western road. 1870
Dunn, John S., Rockvilla Saw Mills, Port-Dundas. 1876
Dunn, Robert Hunter, 4 Belmont crescent. 1878

170 Easton, Robert, C.A., 115 Buchanan street. 1880

Easton, Walter, 32 Exchange sq. 1878
Easton, William J., 150 West Regent street. 1876
Edward, David, 92 Buchanan st. 1878
Evans, Mortimer, C.E., F.G.S., 67 West Regent street. 1873

175 Fairlie, Colin B., C.E., 67 Renfield street. 1874
Falconer, Patrick, 128 Victoria st., Dowanhill. 1876
Falconer, Thos., 50 Kelvingrove st. 1880
Farquhar, John, 13 Belhaven terrace. 1872
Fawsitt, Charles A., Chemical Works, St. Rollox. 1879
180 Fergus, And., M.D., M.R.C.S.Eng., 3 Elmbank cres., *President.* 1868
Fergus, Jas., 5 Burnbank gardens. 1880
Ferguson, John, M.A., Professor of Chemistry, University of Glasgow. 1869
Ferguson, Peter, 4 Linwood ter., Glasgow st., Hillhead. 1866
Fergusson, Alex. A., 48 M'Alpine st. 1847
185 Finlay, Joseph, 9 Montgomerie drive, Kelvinside. 1873
Finlay, John, Moss Park, Albert road Pollokshields. 1850
Finlayson, Jas., M.D., 351 Bath st. 1873
Fisher, Donald, 183 St. Vincent st. 1869
Fleming, William James, M.B., 155 Bath street. 1876
190 Forbes, Alex., Auchingramount road, Hamilton. 1879
Forbes, George, B.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College. 1872
Foulds, John, L.D.S., 151 Bath st. 1877
Foulis, David, M.D., 191 Hill st. 1877
Foulis, William, C.E., 42 Virginia st. 1870
195 Frame, Thomas, Royal Bank place. 1863
Frazer, Daniel, 113 Buchanan st. 1853
Frew, Alex., C.E., Land Surveyor, 175 Hope street. 1876
Frew, Robert, M.E., 75 Bath street. 1874
Fulton, David, C.E., 99 Hill street, Garnethill. 1878
200 Fulton, David, Engraving Works, Duke street. 1872

Gairdner, W. T., M.D., Professor of Practice of Medicine in the University of Glasgow, 225 St. Vincent street. 1863
Galbraith, Andrew, 123 Hope st. 1857
Galbraith, James, M.A., LL.B., 30 Hope street. 1875
Galbraith, William, 3 Blythswood square. 1868
205 Gale, Jas. M., C.E., Water Office, 23 Miller street. 1856
Gardner, Daniel, 36 Jamaica street. 1869
Garroway, John, 58 Buchanan st. 1875
Garroway, Robt., M.D., Rosemount, Cumbernauld road. 1859
Geddes, Wm., Battlefield, Langside. 1846
210 Gemmell, Wm., 150 Hope street. 1876
Gentles, Wm., 338 Sauchiehall st. 1870
Gillies, Wm., Battlefield, Langside. 1869
Gillies, W. D., 96 Miller street. 1872
Gilmour, J. B., 50 North Hanover street. 1865
215 Glaister, John, M.B., 16 Grafton square. 1879
Goodwin, Robert, 58 Renfield st. 1875
Gorman, William, 153 West Nile street. 1860
Gossman, Adam, 79 Robertson st. 1870
Gourlay, John, C.A., 24 George square. 1874
220 Gourlay, Robert, Kirklee avenue, Great Western road. 1869
Gow, Alexander, 2 Dupdune road, Guilford, Surrey. 1869
Gow, Robert, Cairndowan, Dowanhill gardens. 1860
Graham, David, Jun., 140 Douglas street. 1876
Grant, Robt., M.A., LL.D., F.R.S., Professor of Astronomy in the University of Glasgow, Observatory, *Hon. Vice-President.* 1860
225 Gray, Charles, 193 Renfrew street. 1870
Gray, James, M.D., 15 Newton terrace. 1863
Gray, James, 12 Kelvingrove street. 1876
Greenlees, Alex., M.D., 405 St. Vincent street. 1864
Grierson, James, 4 Westbourne gardens, Kelvinside. 1880
230 Grieve, John, M.D., care of W. L. Buchanan, 212 St. Vincent st. 1856
Grieve, Robert, L.R.C.S., Ed., 52 Holmhead street. 1872

Hallows, Frederic J., 12 York buildings, Edinburgh. 1872
Hamilton, Geo., 149 St. Vincent st. 1871
Hamilton, J. Struthers, Adelphi Cotton Works. 1869
235 Hamilton, Patrick, 149 St. Vincent street. 1854
Hannay, Anthony, 23 Exchange square. 1856
Hannay, Jas. B., F.R.S.E., F.C.S., Annfield Chemical Works, Sword street. 1879
Hannay, Thos., 166 Buchanan st. 1864
Hannay, W. H., Clyde Oil Works, Crownpoint road. 1876
240 Hay, John, 12 Terrace street. 1870
*Henderson, John, Jun., 4 Crown terrace, Dowanhill. 1879
Henderson, Thos. Brown, M.D., 17 Elmbank crescent. 1880

Henderson, Thos., 47 Union street. 1855
Henderson, Wm., 88 New wynd. 1853
245 Henderson, W., Williamfield, Irvine. 1868
Henderson, Wm., 15 Cadogan st. 1873
Henry, R. W., 14 Garthland street. 1875
Hewat, A., F.F.A., 41 Elmbank street. 1877
Heys, Zechariah J., South Arthurlie, Barrhead. 1870
250 Higginbotham, James S., 104 W. George street. 1874
Higgins, Henry, Jun., 243 St. Vincent street. 1878
Hill, Andrew, 31 Arlington street. 1877
Hilliard, Joseph, 65 Renfield street. 1878
Hislop, James Daniel, Montgomerie drive. 1874
255 Hodge, William, 15 Hillsborough square, Hillhead. 1878
Hoey, David G., 124 St. Vincent street. 1869
Hogg, Charles P., C.E., 175 Hope street. 1876
Hogg, Robert, 15 Cadogan street. 1865
Holt, T. G., 25 Wellington street. 1875
260 Honeyman, John, F.R.I.B.A., 140 Bath street. 1870
Horne, R. R., C.E., 150 Hope st. 1876
Howatt, James, 146 Buchanan st. 1870
Howatt, William, 146 Buchanan street. 1870
Hunt, Edmund, 87 St. Vincent st. 1856
265 Hunter, A. C., 197 St. Vincent st. 1880
Hunter, James, Newmains house, Motherwell. 1854
Hunter, James, 156 St. Vincent st. 1874
Hunter, J. E., 30 Hope street. 1878
Hutcheson, Robt., 8 Great Western terrace. 1868
270 Hutton, W. R., 149 Hill street, Garnethill. 1868

Inglis, Anthony, 64 Warroch street. 1854
Inglis, John, 64 Warroch street. 1850
Irvine, A. K., M.D., 3 Newton terrace. 1858

Jacks, William, 39 St. Vincent place. 1875
275 Jackson, Thomas, Western Club. 1857
Jacoby, Gustav, Prospect Villa, Montgomery terrace, Mount Florida. 1871
Jamieson, John L. K., 9 Crown ter., Dowanhill 1868
Johnson, Rev. J. S., D.D., Manse, Cambuslang. 1870
Johnstone, Jas., Coatbridge street, Port-Dundas. 1869
280 Jones, William, 286 Bath crescent. 1871

Kennedy, Hugh, Redclyffe, Partick. 1876
Kennedy, Thos., 3 North Exchange court. 1869
Kennedy, Walter Stewart, Allanbank, Crosshill. 1873
Ker, William, 1 Windsor terrace, West. 1874
285 Kerr, Charles James, Greenfaulds house, Cumbernauld. 1877
Kerr, James Hy., 13 Virginia st. 1872
Kerr, John G., M.A., 89 Grant st. 1878
Key, William, Tradeston Gas-works. 1877
King, James, 57 Hamilton drive, Hillhead. 1848
290 King, James, of Levernholm, 115 Wellington street, 1855
Kirk, Alexander C., 17 Hillsboro' square, Hillhead. 1869
Kirk, Robert, M.D., Newton cottage, Partick. 1877
Kirkpatrick, Andrew J., 10 Woodside place. 1869
Kirkwood, Anderson, LL.D., 12 Windsor terrace, West. 1869
295 Kirsop, John, 98 Argyle street. 1855
Koch, W. E., B.A., F.G.S., F.C.S., Parkhead Forge. 1880
Knox, Andrew L., Montgomerie drive, Kelvinside, Great Western road. 1868
Knox, John, 129 West George st. 1870

Laidlaw, David, Chaseley, Skelmorlie. 1879
300 Laing, Alex., LL.D., Professor of Mathematics in Anderson's College. 1846
Laird, Geo., 10 Ann st., Bridgeton. 1870
Laird, John, Marchmont, Port-Glasgow. 1876
Laird, John, Royal Exchange Sale Rooms. 1879
Lamb, Thomas, 190 Parliamentary road. 1870
305 Lang, William, Jun., Clyde Lead Works, Cornwall street. 1865
Leggatt, Robert, 38 Sauchiehall st. 1869
Lamont, Henry, 30 Gordon street. 1880
Latta, John, 138 W. George street. 1880
Leisler, Louis, 130 Hope street. 1869
310 Lindsay, Archd. M., M.A., 87 West Regent street. 1872
Lindsay, Wm. G., 30 George square. 1871
Livingston, Robert, 263B Argyle st. 1879
*Long, John Jex, 12 Whitevale. 1862
Lothian, J. Alexander, M.D., L.R.C.S.E., 6 Newton terrace. 1872
315 Low, James, 176 St. Vincent st. 1878

M'Alley, Robert, Chemical Works, Falkirk. 1872
M'Andrew, John, 17 Park st., East. 1843
M'Arthur, Alex., 82 Glassford st. 1865
Macarthur, J. G., 7 West Princes street. 1874

[illegible]

Mackinlay, David, 6 Great Western terrace, Hillhead. 1855

Mackinlay, John, 29 St. Vincent pl. 1870

570 M'Laren, Robert, Canal street, Port-Eglinton. 1845

M'Laren, William Ed., 13 Exchange place. 1873

Maclay, David T., 169 W. George street. 1879

Maclean, A. H., 124 Queen street. 1870

[illegible] 15 Victoria

[illegible] Lansdowne

[illegible] Belhaven

[illegible] Trongat

[illegible] Montro

[illegible] Derby

[illegible] Scotland st

[illegible] M.R.C.M.

[illegible] 17 A

[illegible] St. B

[illegible] 400

[illegible] cottage.

[illegible] 25 Hope st

[illegible] Dixon str

[illegible] St. Vi

[illegible] Albert road,

[illegible] Ke

[illegible] Pa

[illegible] Sauchiehall

[illegible] st.,

[illegible] F.R.

[illegible] Maryhill

[illegible] Queen street

[illegible] 14

[illegible] 13

[illegible] Kersland terr

[illegible] S., 2 Cla

[illegible] 118 Cheap street.

[illegible] 118 Cheapside

[illegible] Hutchesons' G [illegible] Crown street.

[illegible] 3 Sandyford pl

[illegible] Robert T., M.P., West [illegible] street.

[illegible] Laurel green, Hel[illegible]

Millar, [illegible], 134 Parliamentary

Millar, William, 3 Woodside te

Miller, A. Lindsay, 121 W. Re street.

Miller, Daniel, C.E., 203 St. Vin street.

590 Miller, Hugh, M.D., F.F.P.S., Bath street.

Miller, Jas., Port-Dundas Potte

Miller, James, 21 Woodside pla

Miller, John (Messrs. James Black & Co.), 23 Royal Exchange sq. 1874
Miller, John, 179 West George st. 1879
95 Miller, Thomas, Maxwell terrace, Pollokshields. 1876
*Miller, Thos. P., Cambuslang Dye-works. 1864
Miller, W. M., 5 Shaftesbury ter., West Regent street. 1867
Mills, Edmund J., D.Sc., F.R.S., Anderson's College. 1875
Mirrlees, James B., 45 Scotland street, Tradeston. 1869
00 Mitchell, Angus, 42 Miller street. 1872
Mitchell, Jas. L., 10 Gt. Western ter. 1878
Mitchell, Robert, 54 Carnarvon st. 1870
Moffatt, Alexander, 47 Union st. 1874
Montereau, Emile Louis de, 107 Pollok street. 1877
05 Moore, Alexander, C.A., 128 Hope street. 1869
Moore, Robert H., 3 Armadale st. 1876
Moore, William, M.E., 49 West George street. 1860
Morgan, John, Springfield house, Bishopbriggs. 1844
Morrice, Alexander, Tullymet villa, Ayton road, Pollokshields. 1873
10 Morrison, Donald, LL.D., 4 Victoria terrace, Dowanhill. 1877
Morrison, Geo., 21 Athole gardens, Kelvinside. 1872
Morrison, George R., 12 Colebrooke street, Hillhead. 1875
Morison, J. Crooks, L.D.S., 341 Bath street, 1878
Morrison, James, 98 Sauchiehall st. 1869
15 Morton, Alexander, 241 W. George street. 1869
Morton, James, M.D., Professor of Materia Medica in Anderson's College, 199 Bath street. 1868
Morton, James, Turkey-red Works, Dalquhurn, Renton, 1876
Mossman, John, 21 Elmbank cres. 1870
Muir, John, 6 Park gardens. 1876
20 Muir, Thomas, M.A., F.R.S.E., Beech croft, Partick. 1874
Muir, William R., 345 Bath cres. 1877
*Muirhead, Andrew Erskine, Cart Forge, Crossmyloof. 1873
*Muirhead, Henry, M.D., Bushy Hill, Cambuslang, *Vice-President.* 1869
*Muirhead, Robt. Franklin, B.Sc., 189 Renfrew street. 1879
25 Munro, Daniel, 7 Park quadrant. 1867
Munsie, George, 1 St. John's ter., Hillhead. 1871
Murdoch, James, Glenneuk, Port-Glasgow. 1857
Murdoch, Jas. B., Hamilton place, Langside, 1855
Murdoch, Robert, 16 Main street, Gorbals. 1880
430 Murdoch, Wm., 30 Hope street. 1879
*Murray, David, 169 West George street. 1876
Murray, George, 8 Ingram street. 1872
Murray, George, 18 Carrington street. 1877

Nairn, Archibald, 63 North Frederick street. 1870
435 Napier, James, F.C.S., F.R.S.E., Maryfield, Bothwell. 1849
Napier, James, Jun., 20 Carrington street. 1870
*Napier, John, Saughfield house, Hillhead. 1849
Neilson, Walter, 172 West George street. 1856
Neilson, Walter M., Hydepark Works, Springburn. 1870
440 Neilson, Wm., 58 Bath street. 1871
Nelson, D. M., 48 Gordon street. 1875
Neuhaus, Albert, 1 Prince's terrace, Dowanhill. 1874
Newman, David, 12 Annfield ter., Partickhill. 1877
Nicol, David, 2 Teviot terrace, Kelvinside. 1872
445 Nicol, James, City Chambers, 1872
Nowery, William, 37 Derby street. 1876

Ogilvie, Thomas Robertson, F.C.S., 13 Forsyth street, Greenock. 1875
Osborne, Alex., 5 Oakley terrace, Dennistoun. 1870
Outram, D. E., 16 Grosvenor ter., Hillhead. 1878

450 Paris, Wm., Glasgow Iron Works, St. Rollox. 1869
Paris, William, Jun., Glasgow Iron Works. 1872
Park, James, Millburn Chemical Works. 1877
*Parnie, James, 26 Lynedoch street. 1874
Paterson, Adam, LL.D., 45 West George street. 1843
455 Paton, James, F.L.S., Alnah cottage, Cambuslang. 1876
Patterson, T. L., F.C.S., at John Walker & Co.'s, Greenock. 1873
Peden, William N., 11 Rose street, Garnethill. 1872
Pennycook, C. H., Queensberry terrace, Langside. 1869
Pirie, John, M.D., 26 Elmbank crescent. 1877
460*Pirrie, Robert, 9 Buckingham ter. 1875
Pollock, Arthur, Dillichip Works, Alexandria. 1879

Poynter, John E., 8 Prince's square, Buchanan street. 1866
Pringle, Quintin, B.Sc., B.A., LL.B., 25 Belmont street, Hillhead. 1872
Provan, James, 69 St. Vincent st. 1868
465 Purvis, Robt. T., 176 Kent road. 1879

Ramsay, John, of Kildalton, M.P., 5 Dixon street. 1856
Ramsay, William, C.E., 11 Ashton terrace, Dowanhill. 1841
Rankine, David, C.E., 75 West Nile street. 1875
Rankine, Captain John, 31 Airlie terrace, Pollokshields. 1869
470 Raphael, Robert, 130 Hope street. 1868
Rattray, Rev. Alex., M.A., Parkhead parish, 4 Westercraigs, Dennistoun. 1879
Readman, Robert, 14 Derby ter. 1848
Reid, Andrew, 20 North Albion street. 1875
Reid, James, 10 Woodside terrace. 1870
475 Reid, J. G., 2 Sandyford place. 1874
Reid, Thos., M.D., 11 Elmbank street. 1869
Reith, Rev. George, M.A., Free College Church, 13 Bowmont gardens, Kelvinside. 1876
Remmers, B. H., 63 W. Regent st. 1880
Renfrew, Robert, M.D., 42 Lansdowne crescent. 1877
480 Renison, Wm., 3 Woodside place. 1856
Renton, James Crawford, M.B., L.R.C.P. & S., Ed., 18 St. James terrace, Hillhead. 1875
Ritchie, Wm., Jun., Kincaidfield house, Milton of Campsie. 1870
Roberton, James, LL.D., Professor of Conveyancing in the University of Glasgow, 1 Park terrace, East. 1871
Robertson, Archibald, 25 Queen street. 1863
485 Robertson, Archibald, 36 Hope street. 1867
Robertson, James, Stanley street, Paisley road. 1865
Robertson, John, 10 Valeview ter., Langside, *Librarian.* 1860
Robertson, Robert, 41 Cumberland street. 1877
Robertson, Robert A., Nenthorne, Ayton road, Pollokshields. 1877
490 Robertson, R. Blair, 17 Afton cres., Paisley road. 1872
Robertson, William, C.E., 123 St. Vincent street. 1869
Robertson, Wm., Wellpark Brewery. 1876
Robson, Hazelton R., 14 Royal crescent, West. 1876
Rodger, Robert, 138 West Regent street. 1878
495 Rose, Alexander, 18 Huntly gardens, Dowanhill. 1879
Ross, Henry, 7 Park quadrant. 1876
Ross, James, Wallside house, Falkirk. 1876
Rottenburg, Paul, 130 Hope street. 1872
Rowan, David, 22 Woodside place. 1863
500 Rundell, R. Cooper, Underwriters' Room, Royal Exchange. 1877
Russell, James B., B.A., M.D., 1 Montrose street. 1862
Russell, Thomas, Cleveden, Kelvinside gardens. 1870

Salmon, James, F.R.I.B.A., 197 St. Vincent street. 1870
Salmon, W. Forrest, F.R.I.B.A., 197 St. Vincent street. 1870
505 Sandeman, D., Woodlands, Lenzie. 1870
Schuman, Sigismund, 5 St. Vincent place. 1866
Scott, Alex., 19 St. Vincent cres. 1871
Scott, James, 6 Wilton crescent. 1869
Seligmann, Hermann L., 29 St. Vincent place. 1850
510 Sellars, Jas., Jun., 266 St. Vincent street. 1873
Sewill, Frank, 126 Broomielaw. 1880
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